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A STUDY OF THE FLUORSPAR INDUSTRY OF THE UNITED STATES
WITH RESPECT TO ITS FUTURE

by

Sidney Kincaid Reid

A

T H E S I S

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

D E G R E E O F

Engineer of Mines

Rolla, Mo.

1927

33092

Approved by C.R. Forbes

Professor of Mining.

TABLE OF CONTENTS

V Reserves Contd.
(A) Foreign Reserves
Rngland

V. Reserves Continued

T A B L E S

P L A T E S

A STUDY OF THE FLUORSPAR INDUSTRY OF THE UNITED STATES WITH RESPECT TO ITS FUTURE

I. INTRODUCTORY REVIEW OF THE INDUSTRY

Fluorspar is a compound of calcium and fluorine in the ratio of one molecule of calcium to two of fluorine. By weight it is composed of 51.1% of calcium and 48.9% of fluorine. Its specific gravity is 3.18, a property made use of in freeing it from its associated gangue minerals in gravity separation. Commercially the mineral is referred to as fluorspar and "spar"; its mineralogical name is fluorite. It crystallizes in the isometric system, its common habitat is the cube, but rarely octahedrons are found. The clevage is parallel to the octahedral faces. Its color is variable, white, yellow, green, red, blue, brown to bluish black.

Commercial fluorspar occurs almost entirely in massive form, though some "gravel" deposits contain many well developed crystals. Vugs associated with massive beds or veins in the Illinois-Kentucky district are very commonly lined with crystals of fluorspar, calcite and occasionally barite. The most important deposits of the world are associated with limestone or dolomite strata, but fluorspar is common in veins and cavities in crystalline schists in many parts of the world in the vicinity of later igneous rocks intruding the schists and is disseminated through granite and seyenite in certain areas as though it were a component of the original rock. The deposits are generally thought to be of deep seated magmatic origin.

Fluorspar is consumed chiefly as a flux in the manufacture of open hearth steel. It functions as a slag thinner and assists and hastens the reactions by which sulphur and phosphorus in the metal are absorbed in the slag. The quantity used in the open hearth varies with the nature of the charge and individual practice. During 1925 the consumption of fluorspar per ton of steel manufactured varied from 2.5 pounds to 26.8 pounds and averaged 7.4 pounds according to statistics furnished by the Bureau of Mines. In past years the average fluorspar consumption has been somewhat greater, approximating 8.0 pounds per ton of steel made. (See Tables Nos. II, III and Plate A).

For steel making purposes the spar is used in the form of "gravel". Most of it is made from crude ore by washing, crushing, jigging and tabling and will pass through a 5/8" screen. Natural gravel resulting from the weathering of the original vein formation may contain coarser material, when washed, up to 1" to 1¼" or even larger. Steel makers object to "fines". However, there is no trade specification and jig practice tends to fix the lower limit of gravel size at about 2 M.M. Table concentrates are finer than this and where made they are mixed with the jig product and marketed as gravel.

Under present conditions the standard grade of marketable gravel contains not less than 85% fluorite, not more than 5% silica and 0.30% maximum sulphur. A lower grade, 80% fluorite and 5% maximum silica is produced by some of the mills for the trade which demands it, though this represents only a small percentage of the total. Washed natural gravel in certain cases carries as high as 96% calcium fluoride. The analysis is customarily guaranteed by the producer and in case the quality of the material does not meet specifications, an adjustment on the delivered price is made to compensate the buyer for inferior quality. The adjustment is based on the available net units of fluorite present in the material. Standard gravel guaranteed to analyze not less than 85% calcium fluoride and not more than 5% silica, contains 72½ net units of fluorite. Silica is undesirable and is penalized at the rate of 2½ units of calcium fluoride to 1 unit of silica.

Fluorspar is also used as a flux in foundry practice, mainly in lump form, but not so commonly as in open hearth steel furnaces. On direct inquiry of 192 foundries it appears that 112 do not use fluorspar; 37 formerly used it, but have discontinued its use, and 43 are presently using it. Some foundrymen will accept lumps up to 12" large diameter, a few specify nut size and others various sizes up to 12". Fines are undesirable. Gravel spar is also used in foundries. Practically all of the specially prepared foundry fluxes, marketed under patented trade marks, contain high percentages of fluorspar which form the base of the material. The guarantees and trade usage covering gravel spar also apply to the No. 2 Lump fluorspar sold to the foundry trade.

High or acid grade fluorspar analyzing not less than 98% calcium fluoride and not more than 1% silica is used in making hydrofluoric acid. But trade specifications are affected by the

TABLE I. FLUORSPAR SHIPPED FROM MINES IN THE UNITED STATES BY USES *

USE	1919 %	1919 Short Ton	1919 Avge. Value Per Ton	1920 %	1920 Short Ton	1920 Avge. Value Per Ton	1921 %	1921 Short Ton	1921 Avge. Value Per Ton	1922 %	1922 Short Ton	1922 Avge. Value Per Ton
Steel	86.92	120,199	$23.64	81.01	151,311	$22.43	73.09	25,553	$15.94	86.44	122,403	$16.24
Foundry	.84	1,156	26.06	-	-	-	4.35	1,521	20.14	2.12	2,998	19.02
Glass & Enamel	7.47	10,338	43.02	5.76	10,756	44.11	16.02	5,599	40.03	6.29	8,904	36.29
Hydrofluoric Acid (Including Spar Used in Manufacture of Aluminum).	2.63	3,643	36.96	10.44	19,498	36.86	5.24	1,833	28.62	3.38	4,782	24.81
Miscellaneous	1.04	1,438	26.06	1.31	2,449	27.19	1.30	454	21.23	.15	213	18.02
	100.00	138,290	$25.49	98.52	184,014	$25.29	100.00	34,960	$ 20.71	98.38	139,300	$ 17.88
Exports to Canada	-	-	-	1.48	2,764	23.69	-	-	-	1.62	2,296	17.84
TOTAL	100.00	138,290	$ 25.49	100.00	186,778	$25.26	100.00	34,960	$20.71	100.00	141,596	$ 17.88

USE	1923 %	1923 Short Ton	1923 Avge. Value Per Ton	1924 %	1924 Short Ton	1924 Avge. Value Per Ton	1925 %	1925 Short Ton	1925 Avge. Value Per Ton
Steel	79.80	96,713	$18.23	83.49	104,349	$17.72	80.73	91,760	$ 16.16
Foundry	3.09	3,748	21.20	5.71	7,138	22.35	5.52	6,275	19.31
Glass & Enamel	8.89	10,768	36.17	7.65	9,565	35.05	8.80	10,004	31.23
Hydrofluoric Acid (Including Spar Used In Manufacture of Aluminum)	5.76	6,976	30.19	2.52	3,150	28.39	3.92	4,455	25.60
Miscellaneous	1.52	1,839	20.85	.13	160	21.13	.10	120	39.00
	99.06	120,044	$20.66	99.50	124,362	$19.59	99.07	112,614	$18.07
Exports to Canada	.94	1,144	22.13	.50	617	23.48	.93	1,055	16.66
TOTAL	100.00	121,188	$20.68	100.00	124,979	$19.61	100.00	113,669	$18.06

* U. S. Geological Survey.

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price to some extent. One of the leading acid makers is using washed gravel analyzing about 96% fluorite with low silica. Acid spar is furnished to the trade in lump, gravel and ground form as required.

For use in the manufacture of glass and vitreous enameled ware the spar is ground, either to about 100 mesh (coarse ground) or to approximately 200 mesh (fine ground). Generally speaking, coarse ground is required in the manufacture of glass, while find ground is used in the preparation of enameled ware. For the manufacture of white opalescent glass the spar must be pure white. What constitutes "off color" spar depends on the kind of glass or enamel to be made, but as a whole if it is no whiter than ordinary white stationery, it will be considered "off color". Any pure lump fluorite will grind white regardless of its color in lump form. This is also true of high grade gravel spar, though to a less extent, as the finely divided particles often contain a small percentage of foreign material, shale, clay, etc., which tends to discolor the ground spar. Commercial grades of ground spar for the glass-enamel trade carry from 94 to 97% fluorite and 2½% to 3% silica. The color and analysis are customarily guaranteed by the producer. Material that does not meet specification is rejected. It is shipped in bags, barrels or bulk, as desired by the purchaser.

Of no commercial importance is the use of clear, crystalline colorless spar in making optical lenses. The best of this material is worth perhaps $40.00 per pound, which, of course, is

TABLE 2. SHIPMENTS FROM MINES IN UNITED STATES - IMPORTS & EXPORTS OF FLUORSPAR *

Year	DOMESTIC PRODUCTION Gravel	% of Total Domestic	Lump	% of Total Domestic	Ground	% of Total Domestic	Total Domes.	Imports Short Tons	% of Tot. Dom. & Imports	Grand Total	Stock on Hand at Steel Plants	Acid & Basic O.H. Steel Production Long Tons	Lbs. Fluorspar(All Grds Per L. Ton of Acid & Basic O.H. Steel	
1911	69,825	80.2	4,402	5.1	12,821	14.7	87,048	32,764	27.3	119,812	(a)	15,598,650	15.36	
1912	99,285	85.2	5,315	4.6	11,945	10.2	116,545	26,176	18.3	142,721	(a)	20,780,723	13.73	13.83
1913	101,767	88.0	5,676	5.0	8,137	7.0	115,580	22,682	16.4	138,262	(a)	21,599,931	12.80	
1914	79,276	83.3	8,842	9.3	6,998	7.4	95,116	10,205	9.7	105,321	(a)	17,174,684	12.26	
1915	114,151	83.4	12,033	8.7	10,757	7.9	136,941	7,167	5.0	144,108	(a)	23,679,102	12.17	11.56
1916	133,651	85.8	14,489	9.3	7,595	4.9	155,735	12,323	7.3	168,058	(a)	31,415,427	10.70	
1917	183,144	83.7	25,548	11.7	10,136	4.6	218,828	13,616	5.9	232,444	(a)	34,148,893	13.61	
1918	236,121	89.5	18,944	7.2	8,752	3.3	263,817	12,572	4.5	276,389	57,500	34,459,391	16.04	13.69
1919	122,584	88.6	5,333	3.9	10,373	7.5	138,290	6,943	4.8	145,233	56,000	26,948,694	10.78	
1920	154,786	82.9	19,593	10.5	12,399	6.6	186,778	24,616	11.6	211,394	66,600	32,671,895	12.94	
1921	25,282	72.3	3,779	10.8	5,899	16.9	34,960	6,229	15.1	41,189	30,000	15,549,802	5.30	11.02
1922	126,224	89.1	5,249	3.8	10,123	7.1	141,596	33,108	19.0	174,704	65,000	29,308,983	11.92	
1923	99,140	81.8	11,246	9.3	10,802	8.9	121,188	42,226	25.8	163,414	49,900	35,899,657	9.10	
1924	109,956	88.0	5,080	4.1	9,943	7.9	124,979	51,043	29.0	176,022	64,000	31,577,350	11.15	9.51
1925	97,395	85.7	6,697	5.9	9,577	8.4	113,669	48,700	30.0	162,369	49,400	38,034,488	8.54	
TOTAL	1,752,587		152,226		146,257		2,051,070	350,370		2,401,440	438,400	408,847,670		
Avge.	116,839	85.5	10,148	7.4	9,750	7.1	136,738	23,358	14.60	160,096	54,800	27,256,511	11.75	

(a) Data not available.

* U. S. Geological Survey.

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the measure of its rarity.

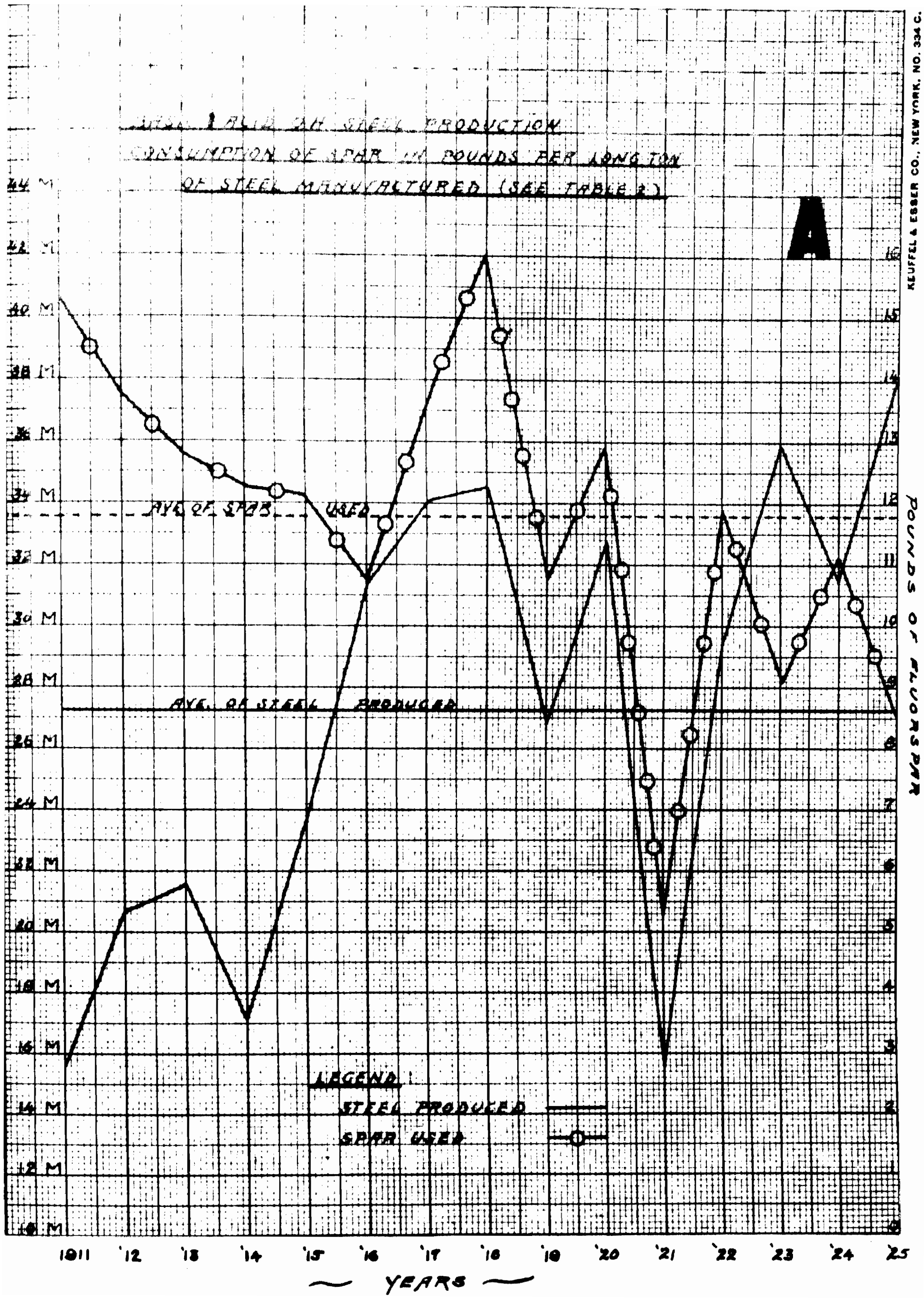
The impurities in fluorspar are its associated minerals and country rock. They vary in character and number in different districts, but their quantity in commercial spar is limited by trade specifications above outlined. In the Illinois-Kentucky district the main impurities are calcite, the main gangue mineral and silica, mainly from country rocks of shale, sandstone and limestone. In the Colorado and New Mexico districts the principal impurity is quartz, the main gangue, and silica from the igneous country rocks with lesser amounts of calcite.

Nearly all fluorspar, especially that associated with limestone or dolomite, carries some lead and some zinc sulphide as well as some iron sulphide (galena, sphalerite and pyrite) or their oxidized equivalents, zinc carbonate, lead carbonate and iron oxide. There are here and there other minor mineral impurities. The sulphate of barium (Barite) is not uncommon. The sulphur bearing materials are deleterious in steel making and foundry practice. With the exception of the zinc minerals, they are satisfactorily eliminated by gravity separation, the lead concentrate constituting a valuable by-product. Sphalerite can be eliminated by fine grinding and flotation, but the fluorite is reduced by this process to approximately 100 mesh and constitutes an unsalable by-product of zinc recovery. It can be retreated by flotation resulting in an improvement in grade though it does not come up to No. 1 ground spar specifications on color and analysis and is sold as sub-standard material at a reduced price. The margin between selling price and the cost of production is therefore close. A few percent of zinc sulphide finely disseminated renders an otherwise good deposit of fluorspar practically worthless.

Table No. 1 shows the uses to which domestic shipments were devoted the period 1919 to 1925 inclusive.

II. CONSUMPTION OF FLUORSPAR

Although no precise figures are available the total consumption of fluorspar in the United States may be derived from statistics of shipments, imports and exports with a fair degree of accuracy. From table II it appears that the average yearly consumption, including exports to Canada during the last fifteen years 1911-1925, inclusive, was about 160,000 tons. During the period 1919-1925, inclusive, 7,876 tons were exported, or an average yearly of 1,125 tons, leaving about 159,000 tons annual consumption in the United States. It may be noticed that the consumption of ground spar from year to year varies much less than that of gravel and lump and seems to bear no close relation to the manufacture of openhearth steel which consumes between 80 and 85 percent of all fluorspar produced, but inasmuch as (a) the manufacture of openhearth steel is a fair index of the state of the entire iron and steel trade and (b) reflects in a measure the industrial activity of the country as a whole and (c) accounts for about 85 percent of the whole consumption, it will be interesting to compare the consumption of fluorspar for a period of years with the manufacture of open hearth steel to discover what the tendency is with respect to consumption of fluorspar, whether it be upward or downward. Up to and including the year 1920, the relationship is fairly constant.


CONSUMPTION OF SPAR IN POUNDS PER LONG TON
OF STEEL MANUFACTURED (SEE TABLE 2)
A
AVE. OF SPAR USED
AVE. OF STEEL PRODUCED
LEGEND
STEEL PRODUCED
SPAR USED
POUNDS OF FLUORSPAR
YEARS
1911
'12
'13
'14
'15
'16
'17
'18
'19
'20
'21
'22
'23
'24
'25
KEUFFEL & ESSER CO., NEW YORK. NO. 334 C.

Grouping the figures and striking averages for periods of three years gives a more constant relationship and shows a better picture of the whole. In the period 1911-13 about 13.83 pounds of spar were consumed per ton of open hearth steel produced; in 1914-16 this figure is about 11.56 pounds; in 1917-19 it is 13.69; in 1920-22 it drops to 11.02 pounds, and in 1923-25 it is only 9.51 pounds, a very striking reduction indeed (See Table II Plate A). The decrease in consumption was real and not merely apparent for stocks at the steel plants at the end of 1919 were about 56,000 tons and at the end of 1925 were approximately 49,400 tons, showing only a slight reduction. Table No. II shows the fluctuation in stocks at steel plants from 1918-1925. There seems to be no satisfactory explanation except the natural resistance of steel makers to post war prices at slightly below war levels. These prices are not merely a matter of policy of the domestic producers for the cost of production of fluorspar did not recede nearly so far as that of general bulk commodities. But whatever the reasons for the high post war prices of spar it seems pretty certain that consumption in the iron and steel trade was adversely affected by them (see Tables III and IV). For a number of years the U. S. Geological Survey has computed each year the average consumption of fluorspar per ton of basic open hearth production. The figures (Table III) show a steady decline from 11.0 pounds in 1918 to 7.4 pounds in 1925. Preliminary figures for 1926 show an even further reduction to 7.2 pounds. The attached chart (Plate A) shows graphically the relation between the production of open hearth steel and the total consumption of fluorspar.

TABLE 3.

POUNDS OF FLUORSPAR CONSUMED PER LONG TON OF BASIC O. H. STEEL PRODUCED IN THE UNITED STATES*

YEAR	VARIATION BY DIFFERENT YEARS POUNDS	AVERAGE POUNDS
1918	-- --	11.0
1919	7.21 to 11.8	10.0
1920	4.8 " 16.1	8.0
1921	4.84 " 18.6	8.2
1922	5.31 " 18.5	7.4
1923	5.80 " 16.2	8.1
1924	5.37 " 19.3	7.8
1925	4.57 " 14.0	7.4

* U. S. GEOLOGICAL SURVEY.

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The foregoing analysis forms a basis on which it is possible to define quite closely what the requirements of fluorspar in the United States may be under a rather wide range of conditions. (a) Under normal prosperous business conditions permitting a reasonable active production of steel about 160,000 to 170,000 short tons of fluorspar will be consumed, of which approximately 13,000 tons will be used by the glass and ceramic industries, about 10,000 tons in the manufacture of Hydrofluoric acid,aluminum, refining of lead, etc., and the remainder will be used by the steel and foundry industries. Expansion of the steel industry and the natural increase in market due to normal growth of the country will be reflected to a certain extent in an increased demand for spar. However, increasingly efficient operation in open-hearth practice and the tendency to decrease the pounds of spar used per ton of steel made will offset any very considerable increase in the consumption of spar under normal conditions (B) Wartime conditions present quite a different picture, steel then becomes of paramount importance. The very maximum production possible is still insufficient to meet demands. Materials that will hasten the production of steel are used without stint. Fluorspar is one of these materials. Referring to table #II it will be noted that during 1918, peak production of steel was reached for the war time period and that year an average consumption of 11.0 pounds of spar per ton of steel made resulted (Table III.) Under similar circumstances the requirements of fluorspar in the

TABLE 4.

AVERAGE PRICES PER SHORT TON OF FLUORSPAR AT THE MINES IN THE UNITED STATES 1913-1925

COMPARED WITH INDEX OF GENERAL COMMODITY & IRON & STEEL PRICES.

YEAR	PRICE PER S.T. ALL DOMESTIC SPAR	INDEX	GENERAL INDEX OF COMMODITY PRICES *	COMPOSITE IRON & STEEL PRICES **	INDEX
1913	6.37	100.0	100	26.32	100.0
1914	5.99	93.9	98	---	---
1915	5.58	87.5	101	24.76	93.7
1916	5.92	92.9	127	40.50	153.9
1917	10.45	164.0	177	70.10	266.3
1918	20.72	325.1	194	56.68	215.3
1919	25.49	399.9	206	50.32	191.2
1920	25.26	396.3	226	65.59	249.2
1921	20.71	324.9	147	40.86	155.2
1922	17.88	280.5	149	37.86	143.8
1923	20.68	324.5	154	44.56	169.3
1924	19.61	307.9	150	40.86	155.2
1925	18.06	283.5	159	38.00	144.4

* CLEVELAND TRUST COMPANY

**IRON TRADE REVIEW.

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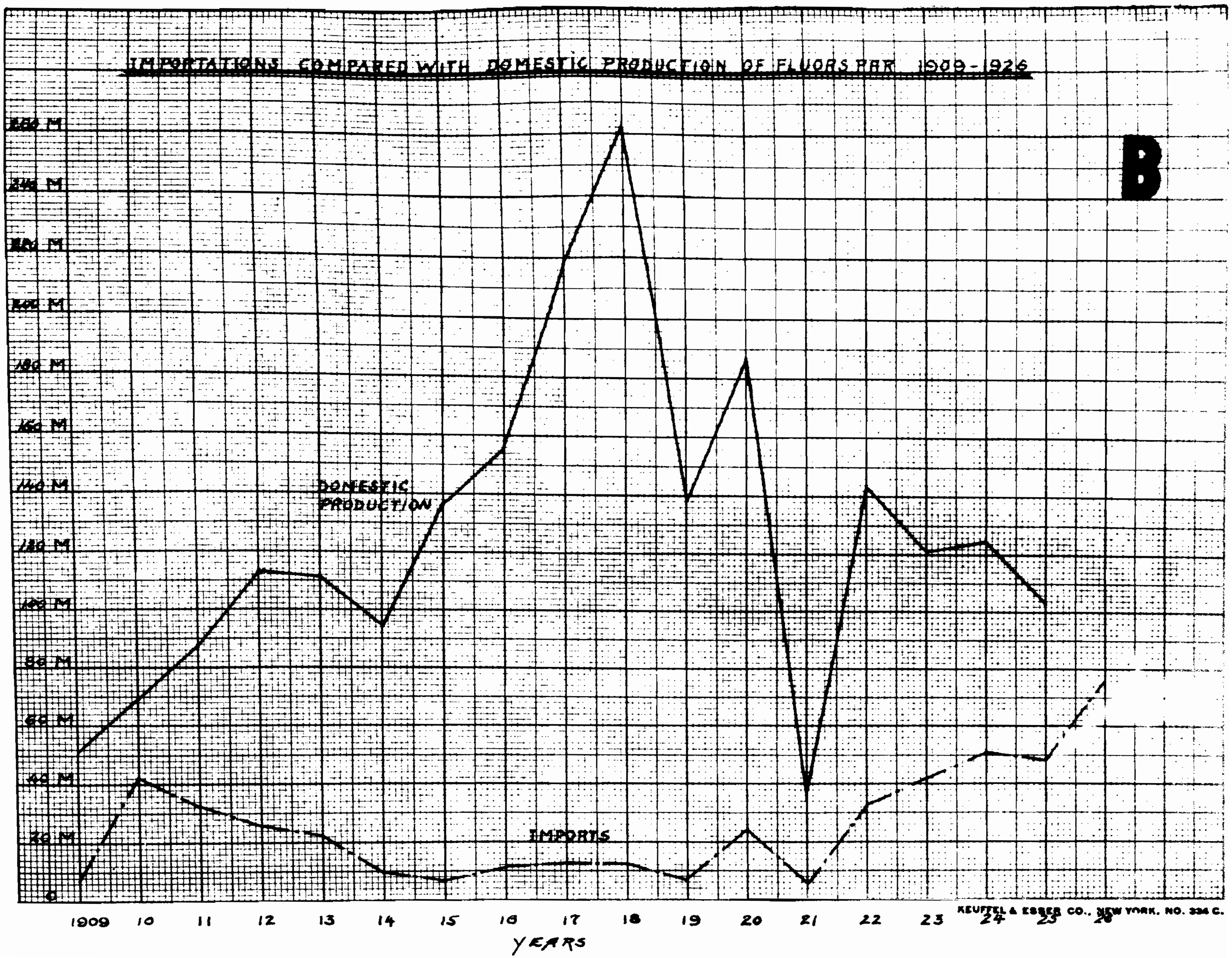
United States conceivably could be double that of normal times. Total shipments (Table II) in 1917 amounted to about 232,000 tons and in 1918 to 276,000 tons. Stocks at steel plants were not built up appreciably so these figures are a fair measure of the requirements during those years under wartime conditions. It is reasonable therefore to assume that an equal amount, say 250,000 tons, annually, will be required again under the same circumstances. Of that amount, the Glass and Ceramic industries would require 13,000 to 15,000 tons; the manufacture of Hydrofluoric acid, aluminum and refining of lead, etc., would take 10,000 to 15,000 tons; the remainder, approximately 220,000 tons would be used by the steel and foundry industries. The chemical specification under stress of wartime demand could be reduced on gravel spar and No. 2 Lump to 80 percent calcium fluoride and maximum of six percent silica without any serious decrease in efficiency, facilitating the production of sufficient spar to meet increased consumption. On the ground spar and high grade lump little decrease in quality could be allowed without detriment to the industries that use those grades. The latter represents a small part of the whole, however, and would be comparatively easy to meet due to producing the additional gravel.


IMPORTATIONS COMPARED WITH DOMESTIC PRODUCTION OF FLUORSPAR 1909-1926
B
DOMESTIC PRODUCTION
IMPORTS
260 M
240 M
220 M
200 M
180 M
160 M
140 M
120 M
100 M
80 M
60 M
40 M
20 M
0
1909
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
YEARS
KEUFFEL & ESSER CO., NEW YORK. NO. 334 C.

III COMPETITION OF FOREIGN SPAR FOR DOMESTIC MARKETS

It appears from Table II that out of an apparent total approximate consumption during the period 1911-1925 inclusive, of 2,401,440-tons 350,370-tons were imported, or 14.60%: The ratio of imports to domestic spar consumed in the period 1911-1925 is shown in Table No.V. The ratio of imported to domestic spar has been rapidly increasing since the war. The accompanying chart (Plate B) shows this relation graphically. It will be noted that since 1921 this increase has been very marked. In 1925 the ratio was 42.84 percent as compared with an average of 14.60% for the 15 year period 1911 to 1925. Imports during 1926 reached a record amount of 75,670 short-tons. These figures show that imported spar is a factor of first importance in an analysis of the fluorspar industry in the United States. There are several reasons for this consistent increase of imported spar since the world war among which are:-

(a) A shortage of ships during the war followed by a surplus of ships after the war. The predominance of ocean traffic is east bound creating an unbalanced movement so that return cargoes are scarce and bulk fluorspar serves nicely as ballast on the return trip.

(b) A relatively greater slump in cost of foreign (Europe and South Africa) production after the war. European labor has always been paid less

TABLE 5 - RATIO IMPORTED SPAR TO DOMESTIC SPAR

YEAR	%	YEAR	%	YEAR	%	YEAR	%
1911	37.63	1915	5.23	1919	5.02	1923	34.84
1912	22.46	1916	7.91	1920	13.17	1924	40.84
1913	19.62	1917	6.22	1921	17.81	1925	42.84
1914	10.72	1918	4.77	1922	23.38		

than American labor. The wages now paid abroad are less than half that paid to American miners. A very large part of the fluorspar coming from England is had from old waste dumps piled up during mining operations for lead ore in the past. Fluorspar was the gangue mineral and at that time of no value. The extent of these waste dumps of spar was tremendous and until they are exhausted, simple milling to concentrate a finished product, costing little, represents the major item in costs. This same condition is true of spar coming from Spain. A demoralized industrial situation in France and Germany has forced wages to a bare minimum and the cost of producing fluorspar is low. In South Africa, native labor is used. Open pit mining is possible on the ore shoot or pipe type of ore body permitting low costs. As a result of these conditions foreign producers can deliver fluorspar on board vessel at port of shipment quite cheaply. Detailed analysis of foreign costs,production and reserves will be given further consideration later in this report.

(c) <u>Low cost of ocean freight as compared with high rail rates in the United States and long hauls of domestic spar to consuming centers</u>.

Vessel rates on fluorspar moving in the United States are low due to an excess of ships, returning light in need of ballast. The three principal ports of entry into the United States, are Philadelphia, Baltimore and Buffalo, (see Table 7). The freight rates from these ports to consuming centers are considerably lower than freight rates on spar from domestic sources. Imported spar entering by way of Philadelphia during

TABLE 6

FLUORSPAR IMPORTATIONS FROM 1909 to 1917. - BY COUNTRIES FROM 1918 to 1925 *

	1918		1919		1920		1921		1922		1923		1924		1925		1926	
COUNTRY	Short Tons	Avge.Value Per Ton	Short Tons	Avge.Value Per Ton	Short Tons	Avge.Val. Per Ton	Short Tons	Avge.Val. Per Ton	Short Tons	Avge.Val. Per Ton	Short Tons	Avge.Val. Per Ton	Short Tons	Avge.Val. Per Ton	Short Tons	Avge.Val. Per Ton	Short Tons	Avge, Val. Per Ton
England	11,659	$12.64	6,041	$15.58	17,096	$8.43	1,644	$7.32	23,836	$8.68	22,862	$ 8.86	29,089	$10.20	21,635	$ 9.02	29,407	$ 9.58
Germany	-	-	-	-	407	23.22	215	20.56	5,804	8.48	8,580	7.88	6,834	10.15	11,680	8.89	20,004	8.33
France	-	-	-	-	-	-	-	-	-	-	-	-	232	11.99	2,537	8.23	11,163	8.13
Italy	-	-	-	-	-	-	-	-	-	-	268	9.22	1,585	9.34	4,278	7.53	1,379	11.19
China	-	-	-	-	-	-	-	-	-	-	90	13.14	506	10.06	559	10.40	645	9.29
So. Africa	-	-	-	-	30	36.00	-	-	486	17.31	10,380	15.19	11,125	13.30	7,906	13.74	8,506	16.05
Canada	913	24.06	902	15.00	7,068	15.64	4,370	12.09	2,877	11.36	-	-	213	15.10	-	-	1,569	9.85
Scotland	-	-	-	-	-	-	-	-	-	-	-	-	276	6.29	-	-	-	-
Holland & Belg.	-	-	-	-	-	-	-	-	71	16.72	46	19.39	1,183	11.86	78	20.82	31	18.25
Spain	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,948	11.50
All Others	-	-	-	-	11	38.73	-	-	34	22.38	-	-	-	-	27	21.89	18	15.39
TOTAL	12,572	$13.47	6,943	$15.50	24,612	$10.79	6,229	$11.13	33,108	$9.04	42,226	$10.24	51,043	$10.89	48,700	$9.63	75,670	$9.87

FLUORSPAR IMPORTED 1909-1917 *

Year	Short Tons	Avge. Value Per Ton
1909	6,971	$ 3.78
1910	42,488	3.18
1911	32,764	2.46
1912	26,176	2.74
1913	22,682	3.15
1914	10,205	3.82
1915	7,167	3.19
1916	12,323	4.38
1917	13,616	8.42

TARIFF ON FLUORSPAR PER LONG TON

Year	$ Per Ton
1909	Free
1909-1913	$ 3.00
1913-1922	1.50
1922-1926	5.60

* U. S. Geological Survey.

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1926, amounted to 38,120 short tons. A large part of this was used at Philadelphia on which there was a low rail freight. Part of it moved by rail into other consuming centers. It is this latter with which domestic producers come in competition as the average value of the spar entering the United States, plus duty, is less than the average cost of placing spar on board cars at mines in Illinois and Kentucky, the competitive domestic field meeting this foreign spar. Referring to Table VIII showing comparative freight rates from ports of entry and domestic producing sources, it will be noted that freight differential into the big consuming centers exists in favor of import spar. From Philadelphia into Pittsburgh the freight rate is $3.68 per net ton as compared with $5.25 per net ton from Rosiclare, Illinois or Marion, Kentucky to Pittsburgh, a difference on a net ton basis of $1.57 per ton in favor of foreign spar. A similar comparison on import spar from Philadelphia into Youngstown, Cleveland and Wheeling, shows in each instance, a freight differential in favor of import spar. In a like manner the rates from Baltimore and Buffalo into these centers of fluorspar consumption show a differential in favor of import spar when compared with rates from domestic sources. This difference is prohibitive to the western producers. Southern Illinois and Western Kentucky share part of this market to a greater or less extent with the import spar, though the import tonnage is steadily expanding. (see plate B and Tables 5 and 8.)

(d) <u>Stimulation of foreign production by agents of eastern and seaboard steel plants</u>.

The average declared value of imported fluorspar enter-

TABLE 7

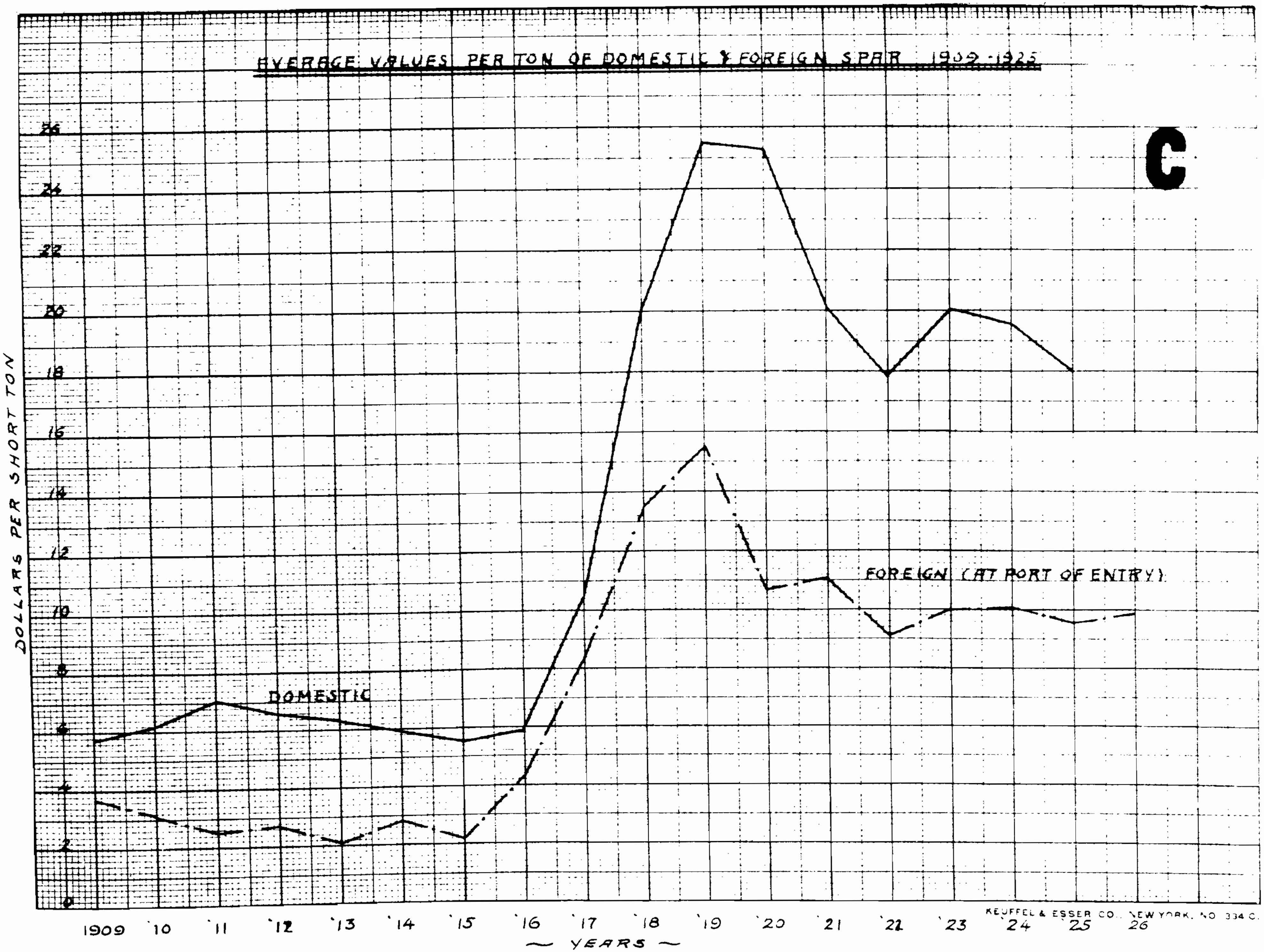
IMPORTS OF FLUORSPAR INTO UNITED STATES BY CUSTOMS DISTRICTS

1924-25-26

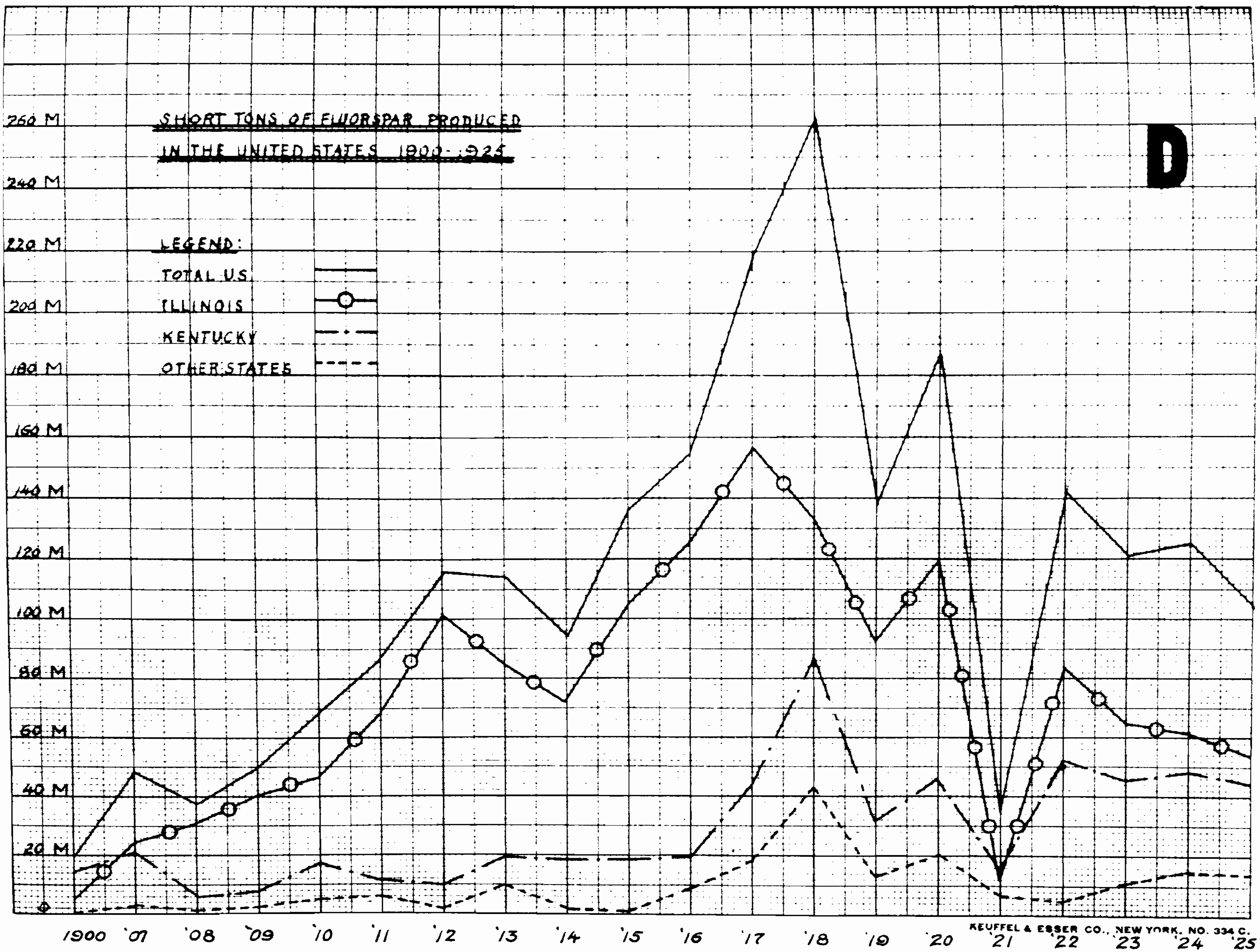
CUSTOM DISTRICTS	1924 LONG	1924 SHORT	1925 LONG	1925 SHORT	1926 LONG	1926 SHORT
PHILADELPHIA	27,431	30,723	24,780	27,753	34,036	38,120
BALTIMORE	6,851	7,673	7,340	8,221	14,206	15,911
NEW YORK	2,093	2,344	2,006	2,247	4,661	5,223
BUFFALO	-	-	2,008	2,249	9,993	11,192
NEW ORLEANS	6,268	7,020	6,405	7,174	3,365	3,769
MOBILE	2,248	2,518	-	-	-	-
WASHINGTON	176	197	274	307	250	280
BOSTON	50	56	202	226	350	392
SAN FRANCISCO	371	416	447	501	535	599
LOS ANGELES	60	67	20	22	64	72
ROCHESTER	2	2	-	-	-	
OHIO	-		-	-	100	112
MINNESOTA	24	27	-	-	-	
T O T A L	45,574	51,043	43,482	48,700	67,563	75,670

ing the United States during 1926, was, according to Department of Commerce figures $9.87 per short ton, all grades. Add to that, duty at $5.00 per ton and an average value of $14.87 per ton is had for all grades. In 1925 the average declared value at port of entry was $9.63 per short ton or with duty, $14.63 per short ton, average all grades. If the higher priced ground spar and high grade lump could be determined and separated, a lower value would naturally result on the gravel grade. In view of the lower price and further, the lower freight rate from Philadelphia, Baltimore, Buffalo, New York, etc., to eastern consuming centers on import spar as compared with domestic spar from Illinois and Kentucky, the consumer of spar in that territory buys foreign spar, thereby stimulating foreign production.

Table VI shows fluorspar importations from 1909 to 1917 with average value at port of entry without duty; from 1918 to 1926, the importations are shown by countries from which produced with the total tonnage and average value without duty at port of entry for each year during the period. The average value per ton of domestic spar produced from all sources in the United States during the period 1880 to 1926 is shown in Table IX. The relation of domestic values to import values (excluding duty) is shown graphically on the accompanying chart (Plate C). From 1909 to 1913, a duty of $3.00 per long ton or $2.68 per short ton on foreign spar was in effect; From 1913 to 1922, $1.50 per long ton or $1.34 per short ton and since 1922 there has been a duty of $5.60 per long or $5.00 per short ton in effect. A comparison



AVERAGE VALUES PER TON OF DOMESTIC & FOREIGN SPAR 1909-1925
C
DOLLARS PER SHORT TON
26
24
22
20
18
16
14
12
10
8
6
4
2
0
DOMESTIC
FOREIGN (AT PORT OF ENTRY)
1909 '10 '11 '12 '13 '14 '15 '16 '17 '18 '19 '20 '21 '22 '23 '24 '25 26
~ YEARS ~
KEUFFEL & ESSER CO., NEW YORK, NO. 334 C.



SHORT TONS OF FLUORSPAR PRODUCED
IN THE UNITED STATES 1900 - 1925
D
LEGEND:
TOTAL U.S.
ILLINOIS
KENTUCKY
OTHER STATES
260 M
240 M
220 M
200 M
180 M
160 M
140 M
120 M
100 M
80 M
60 M
40 M
20 M
1900
'07
'08
'09
'10
'11
'12
'13
'14
'15
'16
'17
'18
'19
'20
'21
'22
'23
'24
'25
KEUFFEL & ESSER CO., NEW YORK. NO. 334 C.

of charts shown on plates (B) and (C) is interesting in that it shows a relation between the volume or tonnage and value of domestic and import spar. The tonnage of import spar from 1910 until 1913 steadily decreased; during the war period and immediately thereafter until 1922 imports remained small but following the depression of 1921, stimulation of foreign sources began immediately in resistance to a high post war domestic value and is evidenced by the steady increase in import tonnage since that time. The difference in value of domestic spar, compared with import since 1922, shown on chart (c) is considerably greater than a duty of five dollars per short ton. This lee way plus an additional favorable differential on freight rates on the rail haul makes foreign spar attractive to buyers in the eastern and Central Market of the United States.

(e) <u>Lower consumption of spar by iron and steel industry in Europe maintains a surplus of production available for export to the United States.</u>

The demoralized industrial situation abroad following the war period and the resultant depression, caused a marked curtailment of all lines of manufacturing. The foreign steel industry was hard hit and the foreign market for fluorspar dwindled accordingly. The surplus sought an outlet elsewhere; the United States received the great bulk of it, a small part going to Canada. Referring to Table VI, it will be noted that England, Germany, France, Italy and South Africa are the major sources of foreign spar. Of these the first four mentioned have experienced an extended, severe period of demoralized industrial conditions. During 1926, England exported 29,407 short tons of spar to the United States as compared with 23,836 short tons in

TABLE 8 FREIGHT RATES ON FLUORSPAR

	TO BUFFALO		TO PITTSBURGH		TO YOUNGSTOWN		TO CLEVELAND		TO WHEELING		TO CHICAGO	
	Miles	**Per Ton**	**Miles**	**Per Ton**	**Miles**	**Per Ton**	**Miles**	**Per Ton**	**Miles**	**Per Ton**	**Miles**	**Per Ton**
Rosiclare, Ill.	829	$ 5.25 Net	700	$ 5.25 Net	706	$ 5.25 Net	649	$ 5.25 Net	819	$ 5.25 Net	386	$ 3.50 Net
Marion, Ky,	780	5.25 "	711	5.25 "	663	5.25 "	582	5.25 "	770	5.25 "	375	3.60 "
New York	406	4.10 Gross	440	4.50 Gross	511	5.03 Gross	567	5.33 Gross	505	4.50 Gross	946	7.50 Gross
Philadelphia, Pa.	414	4.10 "	360	4.10 "	433	4.63 "	488	4.93 "	414	4.10 "	855	7.10 "
Baltimore	408	4.10 "	317	3.90 "	405	4.43 "	446	4.73 "	378	3.90 "	835	6.90 "
Lordsburg, N.M.	2,113	10.20 Net	2,007	10.20 Net	1,996	10.20 Net	1,930	10.20 Net	1,942	10.20 Net	1,684	8.00 Net
Cowdrey, Colo.	1,729	13.40 "	1,651	13.40 "	1,613	13.40 "	1,546	13.20 "	1,716	13.40 "	1,178	9.80 "
Shawneetown, Ill.	820	4.95 "	820	4.95 "	599	4.95 "	532	4.95 "	820	4.95 "	310	3.10 "
Mobile	1,227	17.80 "	1,092	17.80 "	1,084	17.80 "	1,044	17.80 "	1,041	17.80 "	922	6.95 "
New Orleans	1,461	17.80 "	1,271	17.80 "	1,344	17.80 "	1,278	17.80 "	1,229	17.80 "	921	11.50 "
Buffalo	-	-	270	4.30 "	238	4.00 "	333	4.00 "	363	4.40	739	5.50 "

	TO ATLANTA		TO BIRMINGHAM		TO ST. LOUIS	
	Miles	**Per Ton**	**Miles**	**Per Ton**	**Miles**	**Per Ton**
Rosiclare, Ill.	553	$ 4.40 Net	386	$3.80 Net	173	$ 2.40 Net
Marion, Ky.	567	4.00 "	399	3.40 "	114	2.40 "
New York	864	11.00 "	1,031	11.80 "	1,056	8.78 Gross
Philadelphia, Pa.	773	11.00 "	940	11.80 "	962	8.38 Gross
Baltimore	677	10.40 "	809	11.20 "	928	8.18 Gross
Lordsburg, N.M.	1,862	10.20 "	1,694	10.20 "	2,049	8.00 Net
Cowdrey, Colo.	1,722	15.30 "	1,555	14.70 "	1,076	8.40 Net
Shawneetown, Ill.	804	4.00 "	822	3.40 "	167	2.00 Net
Mobile	354	7.90 "	276	2.90 "	805	4.50 Net
New Orleans	522	9.00 "	354	7.90 "	709	10.10 Net
Buffalo	-	14.10 "	-	13.20 "	883	6.90 Net

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1922. Germany exported during 1926, 20,004 short tons as compared with 5,804 short tons in 1922. Similarly for France, a comparison shows 11,163 short tons as against nothing in 1922; for Italy 1,379 short tons as compared with nothing in 1922. Much of this increase is due to decreased consumption in the countries where the spar is produced.

In view of the conditions itemized and discussed above, it is apparent that import spar will continue to supply a large part of the future requirements of fluorspar in the United States unless some arrangement can be effected that will allow domestic spar to recover part of the market now enjoyed by importations. An increased tariff or a decrease in cost of production on domestic spars would accomplish it. This latter is not probable however as existing conditions make it practically impossible.

IV DOMESTIC SOURCES OF PRODUCTION

The main source of production in the United States is in Hardin and Pope Counties in southern Illinois and Livingstone, Crittenden and Caldwell Counties in West Kentucky. This field, which is divided only by the Ohio river, accounted for about 92.8% of the whole production during the period 1902-1925 inclusive. During 1925 this district supplied 87.3% of which Illinois produced 54,428 tons and Kentucky produced 44,826-tons. In Colorado there are two producing properties and in New Mexico several small operations. New Hampshire, California, Arizona, Nevada, Texas, Utah and Central Kentucky have produced fluorspar but their combined yearly contribution is negligible, due to economic disadvantages in production costs and rail freight differentials. A number of these latter deposits are of considerable magnitude but have not been exploited due to the distance from centers of consumption (See Table VIII-IX).

Nearly all of the production of the Western States is consumed in the west but at times shipments are sent as far east as St. Louis, Chicago and Milwaukee. Efforts are being made to stimulate western production for consumption in the Mississippi valley but presently there is little reason to expect much early success for these efforts due to the long rail haul, the undeveloped character of nearly all of the known properties in respect to large scale low production cost and the very general lower grades of the ores as compared to those of the Illinois-Kentucky district. The western ores generally are associated with quartz and igneous country rock which results in a higher silica content than is the case with fluorspar associated with calcite and limestone country rock as in Illinois and Kentucky.

Prior to 1914 little attention had been given to conservation of reserves of spar in the United States. Production was controlled by numerous small and two large operating companies. The great bulk of the production was coming from the Illinois Kentucky district as shown by Table IX. Mining costs were low, fluorspar was plentiful and over-production was usual. Following the outbreak of the world war an expanding steel industry and cutting off very largely all foreign sources of supply combined to absorb this over production and to make greater demands on the fluorspar producers than they had theretofore ever met. Production was increased, new properties were opened, the large high-grade ore bodies were more heavily drawn upon, the most easily accessible ore was taken out and concurrently mining operations rapidly became more expensive as the ore bodies were followed to greater depths. Before 1914 the cost of fluorspar had been low due to the comparatively low cost of mining and the simple type of milling necessary to prepare a finished product for market but as the mines became deeper, the ore became more complex, pumping charges increased and the complex ores required more careful, thoro milling necessitating more extensive milling equipment. During early stages of mining near surface, leaching and weathering had eliminated much of the calcite gangue leaving a high grade crude ore from which a high recovery was obtainable. Deeper, this condition changed, giving place to primary ore. The percentage of recovery of marketable product from crude ore decreased as a result of the change in crude ore until today the average recovery is about 50% whereas before it was 70% or better. By far the greater part of the ore reserves were made up of this lower grade crude ore. The relatively high grade crude constituted only a small part of the whole; was near surface where it was readily available and naturally the wartime demand soon exhausted the cheaper production, necessitating better developed and organized mining operation. Added to the necessity of mining more crude ore to obtain the same amount of finished product were the other difficulties contingent to deeper extension of mine workings. Increasingly large amounts of water were encountered which necessitated the installation of large pumping units. Much more and better timbering was required to keep haulage ways and workings open and to sustain the additional weight encountered at depth. Easily available timber near the mines was cut off and as it became necessary to buy and haul timber, the cost advanced

TABLE 9 SHORT TONS OF FLUORSPAR PRODUCED IN UNITED STATES 1880-1925 *

YEAR	Illinois Tons	%	Kentucky Tons	%	Other States Tons	%	Total Tons	Avge. Value Per Ton
1880-1901	-	-	-	-	-	-	178,117	$ 5.99
1902	18,360	38.2	29,030	60.5	628	1.3	48,018	5.66
1903	11,413	26.8	30,835	72.5	275	0.7	42,523	5.02
1904	17,205	47.2	19,096	52.4	151	0.4	36,452	6.44
1905	33,275	58.0	22,694	39.5	1,416	2.5	57,385	6.32
1906	28,268	69.3	12,528 **	30.7	-	-	40,796	5.98
1907	25,128	50.8	21,058	42.6	3,300	6.6	49,486	5.81
1908	31,727	81.8	6,323	16.3	735	1.9	38,785	5.83
1909	41,852	82.5	7,800	15.4	1,090	2.1	50,742	5.75
1910	47,302	68.1	17,003	24.5	5,122	7.4	69,427	6.20
1911	68,817	79.1	12,403	14.2	5,828	6.7	87,048	7.02
1912	103,937	89.2	10,473	9.0	2,135	1.8	116,545	6.60
1913	85,854	74.3	19,622	17.0	10,104	8.7	115,580	6.37
1914	73,811	77.6	19,077	20.0	2,228	2.4	95,116	5.99
1915	116,340	85.0	19,219	14.0	1,382	1.0	136,941	5.58
1916	126,369	81.1	19,698	12.6	9,668	6.3	155,735	5.92
1917	156,676	71.6	43,639	20.0	18,513	8.4	218,828	10.45
1918	132,798	50.3	87,604	33.2	43,415	16.5	263,817	20.72
1919	92,729	67.1	32,386	23.4	13,175	9.5	138,290	25.49
1920	120,299	64.4	46,091	24.7	20,388	10.9	186,778	25.26
1921	12,477	35.7	15,266	43.7	7,217	20.6	34,960	20.71
1922	83,855	59.2	52,484	37.1	5,257	3.7	141,596	17.88
1923	65,045	53.7	45,441	37.5	10,702	8.8	121,188	20.68
1924	62,067	49.7	47,847	38.3	15,065	12.0	124,979	19.61
1925	54,428	47.9	44,826	39.4	14,415	12.7	113,669	18.06
TOTAL	1,732,924	65.1	737,008	27.7	192,869	7.2	2,662,801	$ 12.87

* U. S. Geological Survey.

** Small Shipments from other States included.

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accordingly. Analyzing these conditions it will be apparent that three complex forces were responsible for increased costs, enumerated as follows:-

(a) Increased cost of mining a ton of crude ore

(1) Advance in cost of supplies
(2) Additional equipment and supplies required
(3) More men employed in mining, pumping, hoisting, etc.
(4) Advance in day wage rate paid labor
(5) Reduction of working day from ten to eight hours and in certain classes of labor from 12 to 8 hours

(b) Increased cost of milling a ton of crude ore

(1) Large milling equipment installation necessary
(2) Additional cost of supplies
(3) More men employed to operate additional machinery
(4) Advance in wages paid labor
(5) Reduction of working day from 10 to 8 hours

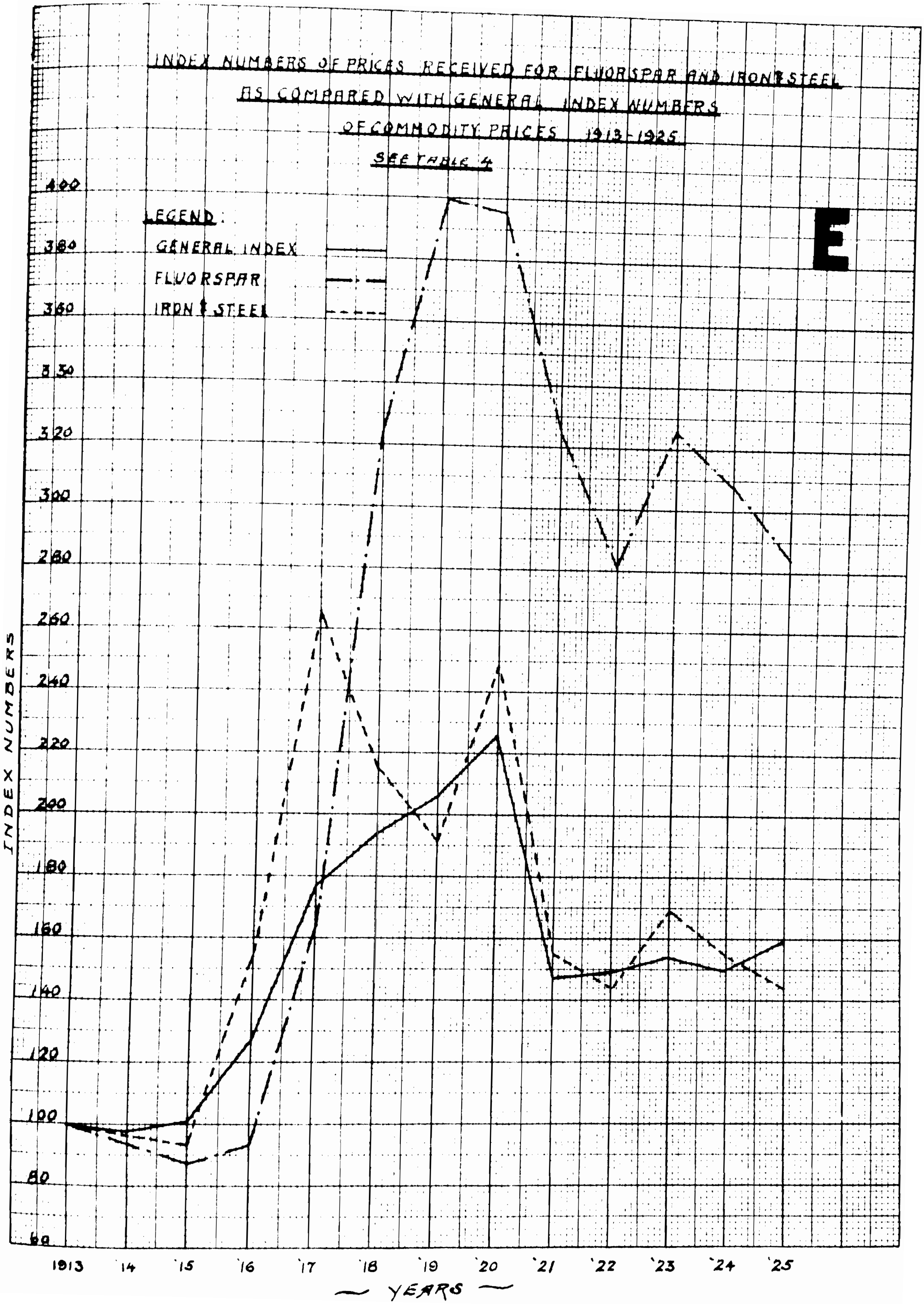
(c) Necessity of mining more tons of crude ore to produce the same amount of finished product to compensate for lower recovery.

The rapidly increasing demand from 1914 to 1918 is graphically shown on the accompanying chart (Plate D). In 1914 there was produced in the United States 95,116 short tons of spar; in 1918 a total of 263,817 short tons were produced. (Table IX). This was made possible by the remarkable advance in price paid for fluorspar. Referring to plate (E), Index numbers of prices received for fluorspar and iron and steel as compared with General index numbers of commodity price - 1913 to 1925, it will be noted that peak price for fluorspar was received during 1919, fell slightly in 1920 and abruptly dropped during 1921 and 1922 with only slight improvement since. Referring to plate (D) the chart shows an abrupt drop in demand following 1918; practically complete inactivity in 1921, with only a moderate demand since. Figures for 1926 are not available but based on incomplete data, it appears exceedingly likely that domestic shipments will show further decrease with a slightly better average price on the tonnage shipped. This compares with an increase in both tonnage and price of importations.

Under the prevailing conditions indicated by these figures, a number of things are apparent, some of which are:-

(a) Western fluorspar cannot be exploited.

(1) Markets in west are limited
(2) Eastern market eliminated by rail freight and foreign competition of importations
(3) No incentive to explore or develop new property



INDEX NUMBERS OF PRICES RECEIVED FOR FLUORSPAR AND IRON & STEEL
AS COMPARED WITH GENERAL INDEX NUMBERS
OF COMMODITY PRICES 1913-1925
SEE TABLE 4
E
LEGEND:
GENERAL INDEX
FLUORSPAR
IRON & STEEL
INDEX NUMBERS
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
1913
'14
'15
'16
'17
'18
'19
'20
'21
'22
'23
'24
'25
YEARS

(b) Illinois and Kentucky field limited to market in Mississippi Valley and Great Lakes Region.

(1) Higher production costs make it impossible for domestic spar to meet import competition east of Pittsburgh and only a division of market is had by domestic spar at Pittsburgh, Youngstown, Sharon and Wheeling districts.
(2) Improbability of any major reduction in production costs of domestic spar.
(3) Tendency to curtail exploration and development expense to reduce costs to a minimum resulting in reduction of proved reserves of ore
(4) Eventual inability of domestic production to meet total domestic demand due to lack of development and contracted facilities.

(c) Further encroachment of Domestic Market by importations.
(1) Unfavorable freight rate differential (Table (VIII)
(2) Stimulation of foreign production
(3) Consistent increase of imports during recent years (Table VI and Plate B).

V RESERVES

The foregoing study of the fluorspar industry in the United States in its various aspects brings us down to a detailed estimate, as far as is possible, of reserves of this mineral. Here there are two primary considerations, (1) the amount of these reserves in the United States, and (2) the extent of reserves abroad. Having determined that, it will be necessary to determine as nearly as possible the rate at which these reserves would be available if required and, further, the maximum yearly production that could be had if another period of wartime demand placed the United States in a position of imperative need of fluorspar.

Before leaving the latter point, let us first outline the various factors upon which the production of a given yearly tonnage depends and the amount that the normal rate can be increased or decreased within the space of a few weeks or months. An appreciation of these controlling factors will assist us to a better understanding of the various classifications into which ore reserves are divided, i.e., developed ore, proved ore, probable ore, possible ore, etc.

1. Milling, hoisting and mining equipment is designed and installed to produce a desired tonnage of material in one or more shifts as the case may be. This means that to increase or decrease production,more or less hours must be worked. The amount of increase is limited by this means to three shift operation if maintenance of equipment and labor supply permit of even that.

2. The organization and personnel of any operation is built to obtain the maximum of efficiency on a normal output. An abrupt increase is greatly hampered and often impossible, due to lack of trained labor capable of manning the operation and in any event invariably results in lower efficiency for a considerable period while the work is being accelerated, even when labor is to be had.

3. Conceding that the foregoing conditions can be corrected and met successfully, it then becomes necessary to produce the additional tonnage of crude ore to meet increased demand considerably in excess of the normal output currently produced. To do that, development must be ahead underground to afford sufficient working places to supply the necessary tonnage. The driving of drifts, starting stopes and arranging haulage requires months of preliminary work on definitely

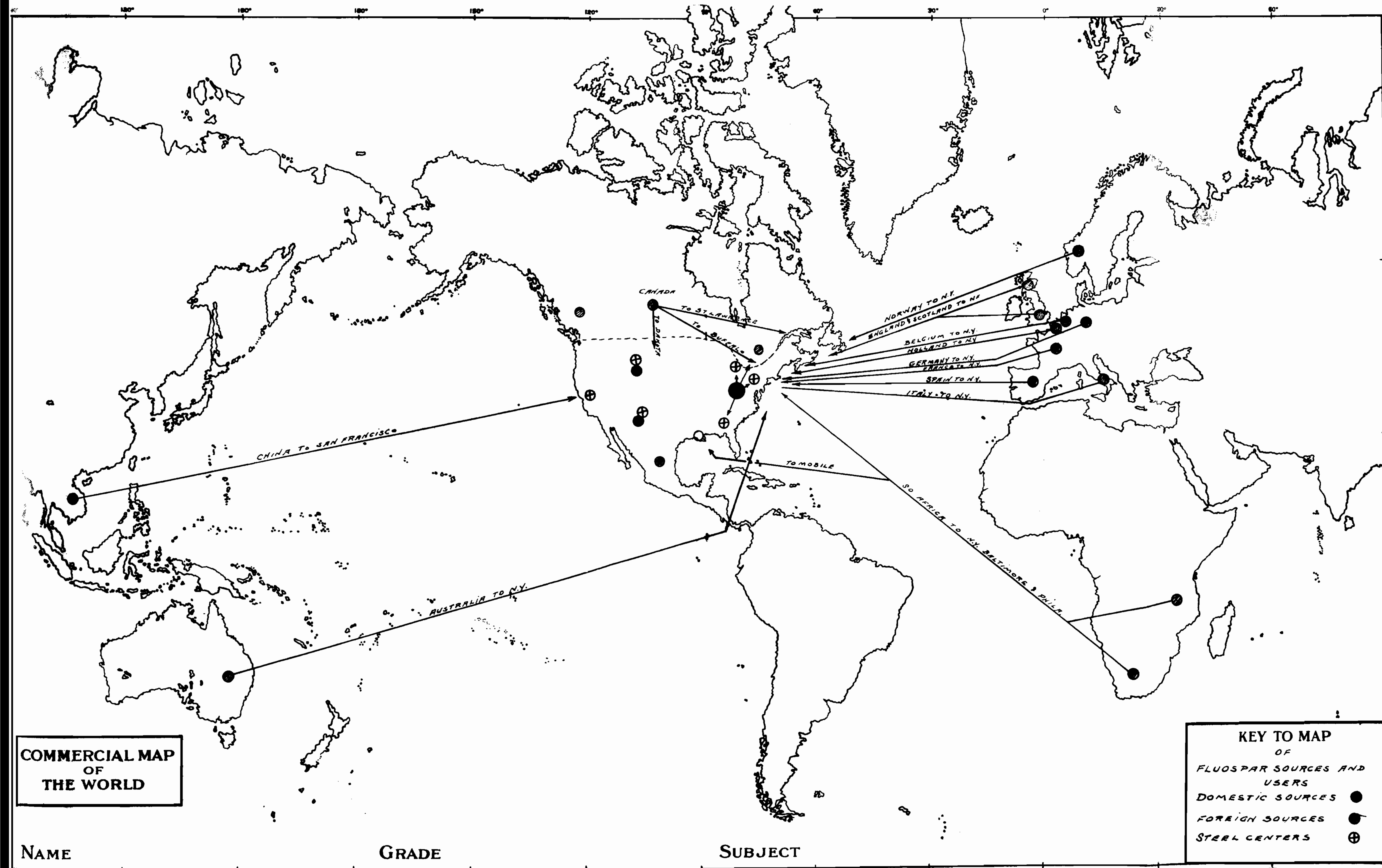
outlined programs covering bodies of known or proved ore. Development cannot be had quickly in the sense that additional equipment can be installed, and is therefore a factor of first importance in determining the rate at which fluorspar would be obtainable if a very marked increase in production were suddenly needed as would be the case if the United States had to depend on domestic resources for the total domestic needs; a condition that would exist if foreign sources were cut off as a result of war.

4. Another factor of almost equal importance is the amount of known or proved ore that is blocked out by exploration work. Development cannot be undertaken until known ore bodies are discovered. Under normal conditions a reserve of proved ore that is adequate would become extremely limited if production suddenly increased by fifty to seventy-five percent. Exploration work is of necessity a slow, painstaking part of mining that is carried on as a part of regular current operation. Long experience and familiarity with a district or property permits the operator to outline, with reasonable assurance, the possibilities that may be expected. Exploration, discovery, development and mining of the ore must, however, be increased gradually over a period of time or a sudden demand merely exhausts a property of the proved reserves in a short time and is followed by a period during which mining is at a practical standstill until exploration and development catch up the reserves that have been robbed. Costs as a result are exorbitant and efficiency of operation is extremely low.

The experience had from 1914 at the start of the world war and particularly during the years 1917 and 1918, with the effects that followed, even through to the present, illustrate what results when an imperative demand for increased tonnage is made on an industry. At no time during those years was development more than a few weeks ahead of production; exploration and development were one and the same; production costs were high and the industry was left with a reserve of proved ore nearly depleted and as a result an unusually high development-exploration charge against production costs to carry currently to build up the reserves of proved ore during post war conditions to a safe margin for continued operation. That has not even yet been achieved.

Importations are of such importance in their far reaching effect on the domestic fluorspar industry that it will be advisable to consider the foreign reserves of this mineral before proceeding to discuss the resources of this country.

Ore is defined strictly as a metal bearing mineral, or combination of a number of various minerals, mixed with barren rock, or waste, which in the aggregate can be mined and marketed at a profit either as crude or "mine run" ore, or as a milled product. It is apparent therefore that prevailing market conditions are one of the big determining factors in classifying mineral deposits as "ore deposits", and it follows that reserves increase as the price received for the mineral; ore that can be mined profitably at one price becomes too lean to consider at a



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lower price and the amount of the reserves decreases accordingly. The conditions existing in the fluorspar field in Illinois and Kentucky before the war illustrate this relation admirably. The immense virgin deposits had hardly been touched; mining could be accomplished cheaply; the quality of the crude ore was very high and in view of the low price received for the product, crude mineral that would yield less than 65 to 70% recovery was not considered as ore. Now a great deal of tonnage is mined, yielding a recovery of approximately fifty percent. Immense tonnage of lower grade material yielding less than fifty percent recovery, however, is still unavailable at present market values.

The price which is paid for imported fluorspar is determined by that paid for domestic spar. Referring to plate (C), it will be noted that during post war years this relation is quite marked. Assuming, therefore, that the actual price paid for fluorspar will remain about as at present and that relief in the form of additional tariff will serve only to allow domestic spar to penetrate somewhat further east, regaining the east central market now largely held by foreign spar, the values received for import spar on the somewhat reduced tonnage that would enter the United States would be as at present. This gives us a basis upon which to consider foreign reserves of this mineral, keeping in mind that any increase or decrease in price would have direct bearing on the available amount.

(A) FOREIGN ENGLAND

During the latter part of August and the first part of September, 1925, Mr. R. C. Allen, made a trip abroad expressly to determine as nearly as possible the exact conditions surrounding the production of fluorspar in England, France, Germany, etc. The following is taken from the report Mr. Allen made on his observations in England:

> "England possesses, in Derbyshire particularly, vast reserves of fluorspar measured by the standards we are familiar with from studies in the Illinois-Kentucky field, and is in position to continue to produce large tonnages of fluorspar of fluxing grade at low cost for an indefinitely long future. English gravel and fluxing lump are being delivered at our Atlantic ports, on cars duty paid, at from $13.00 to $16.00 per ton; so long as wage and price levels remain in England as they now are, there will be no increase in the cost of English production. I believe that with more enterprise and better management the average cost of English spar can be reduced, or to put the matter another way, even should wage and price levels advance, these factors of cost could be counter-balanced by better methods of production.
>
> At this point I may refer to a peculiar situation affecting the production of fluorspar mines in England. By laws of ancient origin the lead in most of England belongs to the Crown. In certain parts of the producing areas, particularly in Durham, these rights have been transferred by the Crown to the Church of England. Generally speaking, there is an open season on lead all the time, if I may be permitted to so express myself. A prospector is free to enter on any private property and dig for lead, and so long as he keeps working, is secure in his possession of the premises, his only obligation being the payment of one-fourteenth of the lead he produces to the Crown. Fluorspar in Derbyshire particularly is produced largely from properties which have been "jumped" for lead. Having "jumped" an idle property for lead, the prospector must make some arrangement with the land owner for the fluorspar and this, I am informed, is easily done by an offer to pay one shilling per ton for the spar, the prevailing rate of royalty in both Durham and Derbyshire. In Durham the lead rights in most of the spar producing veins seem to be controlled by the Weardale Lead Co., partly at least and perhaps wholly, so far as my information extends, by an arrangement with the Church of England, but in Derbyshire where all of the land is owned by the Crown, there are many spar

bearing properties which may be "jumped" by anyone so desiring. This "jumping" is going on more or less all the time. Having "jumped" the property, it is necessary to keep it in continuous operation to protect one's self against other persons desiring to "jump". Therefore any considerable bulge in the value of fluorspar is bound to bring additional properties into operation, but the bringing in of such properties would soon take the bulge out of the price. The only thing, therefore, that could stiffen the price of English spar would be a growing shortage of the mineral or a rise in the cost of its production. Unfortunately neither of these factors are apt to be operative for an indefinite future period.

A good deal has been said about the approaching exhaustion of the English hillocks, that is the old spar dumps accumulated during lead mining. I began to hear of this in 1919 when my attention was first drawn to fluorspar, and somehow it seems that American producers have been hopefully expecting year after year a stiffening of price with the approaching exhaustion of the hillocks, but the fact is that these hillocks (they are confined mainly to Derbyshire) still contain a heavy tonnage of fluorspar, probably a quarter of a million tons, mainly gravel. The English consumer has subsisted on lump spar mainly from these hillocks, and even now is reluctant to buy any gravel, even milled gravel. Little attempt has ever been made until recently to treat the gravel in these hillocks and that portion of them which has been shipped as gravel has been an unwashed, low and uncontrollable grade of material. Practically all of it has gone to the United States and some is still being shipped to our ports, but two factors have begun to change the character of the English spar industry. One is the growing scarcity of lump spar from the hillocks and the other is the insistence of our eastern steel manufacturers on a higher and controllable grade of imported gravel. The English steelmaker must be supplied with lump mainly from underground works, the American steelmaker with milled gravel from the hillocks and underground works. This milled gravel, I think, will eventually find favor with the English consumer, although at this time he generally insists on lump.

Although, generally speaking, spar production in England remains in a primitive condition, milling has begun at a number of properties within the past several years and the future is bound to see more and better mills. This change of practice on the part of the English spar producers is already reflected in the better reputation of English spar in our eastern markets. The margin of preference for domestic gravel is disappearing and I will be surprised if it does not entirely disappear within the next several years.

All of the American producers are struck with the primitive methods of English production, but I must say that I was surprised at the apparent lack of enterprise and ingenuity in England where industry generally is in a high state of development. Such milling as is now attempted has been brought about it appears through the enterprise and pressure of American agents of English producers. To illustrate what I am getting at here I may refer to the surprising fact that the log washer, a device known in America for several generations, has been patented in England within the past year by the Clay Cross Co. and two have been recently put in operation. Hand washing is giving way to power washing and although, as I have said above, improved methods have only begun, I expect to see rapid development and therefore a keener competition in the future of English spar in the United States.

Another factor increasing the pressure of English spar on American markets is the bad state of English iron and steel manufacture. The high grade iron ore and coal of England can no longer be produced at a cost comparable with that of the European continent and America. This is generally attributed most largely to the influence of labor unions in England, but the cost would be higher under any circumstances and, despite labor agitation in England, the wage is not nearly so high as it is in America where the cost of coal and iron ore is much lower. It may be that conditions may come about under which the English iron and steel manufacture can revive, but it is difficult to see just how such conditions are going to come about; until they do, a portion of the spar heretofore used in England will seek a market elsewhere.

Furthermore, in considering our competition from England it must not be forgotten that lead is an important product of these mines. The hillocks are, of course, lead free or nearly so, but with few exceptions the ore mined underground is more or less charged with lead, particularly in Durham where the most important operator, the Weardale Lead Co., seems to be chiefly engaged in lead mining, fluorspar being a by-product. All of the English spar mines were originally lead mines; so far as I was able to observe or learn, there is in Derbyshire and Durham not one producing vein of fluorspar that was not worked for lead prior to the time fluorspar became valuable. These workings date back to the Roman occupation in the eleventh century and lead mining has been going on more or less continuously, if desultorily, down to the present. Lead mining seems to have been carried on in the most primitive manner, only the richer ores being moved. When any considerable difficulty was encountered, such as bad ground or water flow, workings seem to have been suspended. Drainage of the mines was accomplished by driving adits from the valleys and although some pumping has been done, 200 or 300 gallons of water per minute seem to have been fatal everywhere to these operations. In both Derbyshire and Durham the topography is semi-mountainous, the ridges rising from 400 to 700 or 800 feet above the valleys, therefore tunnel drainage made available impressive tonnages of ore above the drainage level. So far as I could learn there has been mining at considerable depths below drainage levels, depending upon the flow of water to be handled by pumping. The old lead workings are on some of the veins very extensive, not measured in feet or rods but in miles. Wherever in these workings the gangue material is fluorspar, the greater part of the spar is without much question remaining underground, partly broken and partly standing in its natural condition. This being true, it follows that there are in Derbyshire and Durham reserves of fluorspar to be measured only in millions of tons.

To give you a clear understanding of the above remarks you may consider the original character of the lead-spar veins and the manner in which they were worked by the old miners of lead. Where the lead is associated with spar in these veins it originally stood very commonly in rich bands called "ribs"; these ribs were often in the center of the vein, resting frequently on one or the other of the walls. That portion of the vein not occupied by the lead ribs consisted of fluorspar (and in Derbyshire also calcite and barite in places, and in Durham vein quartz) with lead disseminated in grains and patches in the body of the spar. Such ore was called by the old miners "brangled". The brangled portions of the vein were not rich enough to afford profitable working for lead and are in large part still intact. There are portions of the veins, of course, which contain little or no lead and these portions remain intact. It is very interesting to observe in the underground workings of these lead spar veins the persistency with which the old miners followed the lead ribs. There are openings little wider than the body of a man which have been cut out for hundreds of feet. It appears, furthermore, that where it was necessary to break the spar along with the lead the ore was hand-cobbed underground, the spar being left in the mine as gob. Therefore, on reopening these old mines the modern miner finds a good deal of spar which requires only loading and transportation to the surface.

Statements have been made by some observers to the effect that it would be necessary to begin to install pumping plants immediately in order to supply the English market. Such statements are wide of the truth. In all England I saw pumps.at work in only one mine, and these were handling 150 gallons per minute. Very large quantities of spar remain in Derbyshire, particularly above the old drainage levels mentioned above, and although it may be here and there profitable to install pumps in order to get at virgin portions of the vein or heavier lead bearing material below water level, it is not necessary by any means in order to sustain present production for many years to come."

I - DERBYSHIRE DISTRICT

In this district in England there are a number of deposits, all of which have been operated to a more or less extent above water table, the larger of which are:-

(1) Crich Hill - traversed by three intersecting sets of veins, one striking northwest, one northeast and the third bisecting the angle of intersection of the first two. All of them carry lead and fluorspar and have been worked for lead first and for lead and fluorspar subsequently down to the present time. None of these latter workings has extended below the old lead mining operations. The standard wage at Crich is one shilling per hour, boys receive nine pence, the best miners one shilling, three pence. Tonnage from these operations is on the market at about $6.00 per long ton and would cost at Atlantic ports in the United States as follows:

At point of shipment	$6.00	
Freight to port of shipment	2.25	
To cars Atlantic port	3.00	
	11.25	per long ton
	10.45	" short "
Duty	5.00	
Cost at Atlantic port	15.45	" " "

It is impossible,to arrive at any estimate of the reserves at Crich. No doubt there is a considerable tonnage of spar available below water level and in the old lead working left as waste, to continue production at the present rate for several years and probably longer.

(2) Ashover- Here there are a number of veins, all of which are spar bearing and as elsewhere in Derbyshire have been worked for lead by the ancients (Romans) and more or less continuously if desultory down to the present. A demand

for spar in recent years has made the heavier lead bearing mineral available, lead being the by-product. Production continues also from the "Hillocks" or old waste dumps and what remains of them is now being milled for gravel. It is estimated that there has been produced here approximately 200,000 tons of spar. There is no means of calculating satisfactorily the reserves but the district in all probability will continue to produce for many years at a rate at least equal to that in the past.

About 1923 a small mill was built to concentrate this crude ore and Hillock material which was the first attempt at spar milling in England.

The wages at Ashover range from 9 pence to 1 shilling 3 pence per hour, averaging about 1 shilling. Metallurgical gravel sells for $3.60 per long ton on cars at mine. On this base it is delivered in Atlantic ports in the United States for :-

Price at mine	$3.60	per long ton
To port of shipment	2.25	" " "
On board cars at Atlantic port	3.00	" " "
Price f.o.b. cars	8.85	" " "
	8.00	" short "
Duty	5.00	" " "
Total	13.00	" " "

(3) Matlock-Cromford - The fluorspar deposits here occur in veins and pipes extending in some cases (Mole Trap Lode) outward beneath the overlying shales. The spar carries lead quite as abundantly as in other deposits in Derbyshire.

There are no mills of any kind in the area, the gravel is unwashed and other grades are hand picked. All mining is done by hand drilling and mucking in the most primitive manner.

Masson Hill - All of the mines with the exception of the Oxclore Pipe at Snitterton and the Mole Trap Lode near Cromford are on Masson Hill; it forms the northeast projection of the limestone area and rises four hundred feet or more above the valley of the river Derwent which encircles its base. Beginning at the south end of the hill in the outskirts of Matlock Bath is first:-

(a) The Lock Mine - reopened during 1924 for spar. The vein strikes east-west and can be followed for about three quarters of a mile by a line of old shafts and hillocks. Former operations many years ago were for lead. There is no way of estimating reserves though they are considerable judging from the length of vein revealed at surface and width of spar five feet and better evidenced in present workings.

(b) Ball Eye Mines - A series of pipes in limestone northwest of the Locke Mine. These pipes are nearly exhausted of fluorspar and lead and reserves are small as a result.

(c) Cathedral Pipe - The northernmost of the series of pipes above mentioned, and the largest, still contains a good deal of spar. Thickness of nine feet of good spar are in place on the walls of old irregular, cavernous openings and tortuous passages excavated for lead. The workings appear to contain a considerable quantity of spar, but there is no basis of hazarding even a guess of the resources available here. During the last two years a small production has been had and will probably continue indefinitely.

Adjacent, higher on the hill is a series of old dumps carrying fluorspar which mark the course of three veins. The veins have not been worked for spar but have possibilities for future production.

(d) Bonsall Low Mine - Continuing northwest from Cathedral Pipe the Bonsall Low Mine is encountered. The vein where opened at surface shows six feet of pure white high grade spar. The out crop may be followed east about three quarters of a mile by remains of old hillocks at abandoned lead shafts. There is a very considerable reserve of spar in this vein, and very excellent prospects for a much larger operation than is now conducted on the property.

(e) King, Roman, High Loft, Black Ox Mines and Hopping Pipe, - are a series of apparently connected pipes on the upper slopes of Masson Hill facing the Valley of the Derwent River east of Matlock. This series of pipes is said to be shallow, at no place extending more than 200 feet below surface. The King and Roman are said to be virgin ground so far as underground spar mining is concerned and to have large reserves, Judging from the surface dumps, this is true.

At the High Loft and Black Ox mines (pipes) there are large dumps of excellent milling spar which will produce not less than 75,000 tons of recoverable gravel spar. The High

Loft and Black Ox are reported to be worked out underground.

The Hopping Pipe mine is said by two observers, Carruthers and Pocock (1923) to have very large reserves of uniformly high grade spar and placed the possible output at 150 tons per week.

Summarizing, this series of pipes will produce an ultimate gravel production from underground reserves and surface hillocks, amounting to not less than 200,000 tons, probably considerably more, if properly developed and will be a source of production for many years. Labor will constitute almost the whole production cost as there is little or no water to pump and the mining conditions are good.

(4) Porter Way Mine - is located a slight distance north of the village of Winster among some extensive ancient lead workings. The pipe does not come to surface so far as known. It was worked for lead many years ago. Dr. C. S. Garnett, F.C.S., F,G.S., a highly trained geologist and metallurgist examined some of these old workings and states that the pipe is up to 510 feet wide, that the quantity of spar is enormous certainly in excess of one million tons but how much in excess one can only conjecture and that it is undoubtedly one of the greatest deposits in England. Mining is being carried on in a small way and a small production of gravel has been made.

(5) The Oxclore Pipe - has been worked in the past for lead over a length of more than a mile. The deposit has an east-west strike. One of the old lead shafts is sunk to a

known depth of 600 feet and is said to be down to a total depth of 1,000 feet . As in other old lead workings only the rich lead ore was mined, leaving the fluorspar as far as possible as waste in the ground and much of the low grade lead ore still remains in place with this spar. The depth of the shaft and the lateral extent of the workings indicate the magnitude of the deposit.

There is approximately 75,000 tons of gravel spar available on surface through milling of the old waste dumps or hillocks. These hillocks have been picked over for the high grade lumps but that remaining is of good mill quality.

The total reserves available in this deposit are enormous. A conservative estimate would be about one million tons of spar with perhaps a maximum of twice that much.

(6) The Mole Trap Lode - is a vein trending east-west which can be traced for a distance of about one and one half miles. Its eastward extension beyond this limit beneath overlying shales is unknown. The old hillocks or waste dumps of spar from former operations have been shipped as marketable high grade spar. The vein is from 6 to 8 feet wide, unusually rich in lead, no barite of any moment, some zinc (sphalerite), very little silica and mainly hard white fluorspar. The vein was last operated fifty years ago for lead, down to comparatively shallow depth, where water, then considered heavy, was encountered. Modern pumps would readily handle the flow of water considered heavy fifty years ago.

Lead as a by-product would pay very largely the mining costs of fluorspar from this deposit. The quality of the spar is excellent.

The reserves here are extensive. Any estimate of the available tonnage could at best be only a guess. Judging however from available data there is not less than 750,000 tons and probably a great deal in excess of this figure.

(7) The Great Rakes System - includes three of the greatest lodes in Derbyshire. The principal producing vein in the area is marked by hillocks of most impressive dimensions and contain not less than 75,000 tons of spar of merchantable quality. Barite associated with the spar will make milling necessary to prepare the spar for market if the quality is maintained at standard grade. Hillocks on some of the veins south of the main vein above mentioned are also being worked for gravel and lump spar. There is no underground mining.

The main vein is, in places, up to 51 feet wide. Here again the available reserves are not possible to estimate at all accurately. Judging from available data, however, there is at least 1,500,000 tons in place with good possibilities of considerably more. Supplementing this, reserves on smaller veins in this area would increase the total to well over 2,000,000 tons.

(8) Evam, The Globe Mine and Bradwell District - Here as elsewhere in Derbyshire, former operations were conducted for lead. The spar was left as waste and the hillocks are being

worked in a haphazard way for lump and gravel. These old dumps are now practically exhausted. Little is known of the reserves but judging from experience elsewhere in the district they doubtless exist in some quantity.

II - DURHAM

The entire production from County Durham is now coming from the valleys at the river Wear above Stanhope and its tributary creeks. The producing area is not more than fifty square miles in extent. The river Wear and its tributaries are deeply incised, the valley floors being 500 to 600 feet below the crest of the intervening ridges and all the veins (there are no pipes) with one exception are being worked by adits above natural drainage levels. Lead is an important by-product in the production of spar, just as in Derbyshire.

Mining of these deposits below water level has not begun, though in one instance a small pumping plant has been installed and the water lowered a few feet. These deposits, so far as known, are deep seated and persistent at depth. When mining operations extend below water level a revival of lead mining (and incidentally spar production) is inevitable. The principal sources of production are:-

(L) The Barbary Mine is opened over a length of about 900 feet. The vein is between five and six feet wide. The spar is of good quality, carrying considerable lead. The vein can be traced for more than a mile and characteristics of the vein where opened by workings and available for inspection, together with its length, is indicative of its reserves.

It will be interesting to calculate the cost of spar from this district in Atlantic ports:-

Cost of spar Middleborough	35 sh. per long ton
Royalty	1 " " " "
Boat Freight	12 " 6p " " "
Insurance & Shrinkage	1 "
Cost at Atlantic ports	49 sh. 6p " " "
or approximately	$12.03 per long ton
Expressed in short ton	10.61 " short "
Duty	5.00
Cost in Atlantic port with producer's profit	$15.61 " " "

If the value of the lead is credited to mining costs the spar would cost 3 to 5 dollars per ton less or approximately $10.50 to $12.50 per ton.

(2) <u>Sedling Vein</u>: has been worked in the past for lead. It is about five to six feet wide and has not been worked below water level. Sufficient data is not available to estimate reserves, though below water level there will be a very considerable tonnage.

Two mines, the Hinchcliffe and Sedling are now in operation on the vein producing spar. The crude ore runs rather high in silica and two simple small mills are used to concentrate the marketable ore.

(3) The Slitt Vein has a known extent of more than six miles. There are four mines on the east end of the vein occupying about three miles of the vein. Reserves here are of considerable extent, but insufficient data does not permit of making an estimate. The extent of the working and the length of vein, however, would indicate reserves to the extent

of several hundred thousand tons.

(4) Stanhope District - Several small mines are being operated here on different small veins. Former mining as elsewhere in the district was conducted here for lead. The spar is of poor quality, but there is a considerable reserve of it, such as it is. Present operations are conducted mainly for lead, a small production of spar resulting as a by-product.

III. Fluorspar is also found in other parts of England in more or less quantities, but these sources are of comparatively little importance in view of the tremenduous reserves in Derbyshire and Durham. These other sources are (1) Northunberland, (2) Yorkshire, (3) Cumberland, (4) Cornwall and (5) North Wales (Flintshire)

GERMANY

Commercial deposits of fluorspar in Germany occur chiefly in: (1) Harz district in central Germany. The spar veins here are closely related to the silver veins. There are several deposits, chief of which is north of Stollberg. It is slightly less than ten meters in width and during 1924 produced approximately 24,000 tons. At other deposits, fluorspar is a by-product from the production of silver and lead. No information is available regarding reserves. This district has been in active operation since before 1896.

(2) Thuringia has large deposits of fluorspar which are being actively exploited. Much of the spar is very pure

though in places is obtained as a by-product from the mining of barite. More than ten active operations are in progress presently. The veins vary in width from one meter up to six and seven meters. One deposit alone is estimated to contain not less than 300,000 tons with possibilities of several times this amount. The district as a whole contains very large reserves, amounting to several millions of tons.

(3) Bavaria contains upwards of twenty fluorspar mines. The deposits are large, the spar is of good grade and in some cases associated with lead and zinc which is recovered in milling the ore. One mine alone is estimated to contain 1,500,000 tons of proved and probable ore. The possible will double that amount. Reserves for the district as a whole amount to several million tons.

(4) Baden in Southwestern Germany - There are a number of deposits which are being worked presently. Mining is conducted through adits and tunnels into the veins from the mountain side. The reserves of proved and probable ore at one property are estimated to be 600,000. The possible ore is considerably more than this, making a total reserve for that property in excess of 1,200,000 tons. Reserves in the district as a whole amount to several million tons.

The indications are that Germany will have a considerable surplus of fluorspar for export as the reserves are large and production has been stimulated by market conditions both in Germany and the United States. The German fluorspar industry is well organized and a steady improvement and moderization of mining and milling is in progress during recent years. During 1924 Germany produced approximately 70,000 tons, divided about as follows:

Bavaria	21,630	tons
Prussia	24,101	"
Saxony	4,616	"
Thuringia and Baden	20,000	"
Total	70,347	"

Referring to table (6), it will be noted that imports from Germany into the United States increased from 407 short tons in 1920 to 20,004 tons in 1926.

FRANCE

Fluorspar deposits occur in France in the Houte-Loire district near Langeac, Paulhauget and Briode and at Vaux-Rebard in the Rhone district. At Romaniche fluorspar is said to occur associated with manganese. Development under way in the Department of Var contemplates a production of 2,000 metric tons per month beginning the latter part of 1927.

Little is known about the ore reserves, as scanty development has been done. Indications are, however, that the tonnage will be large enough to support present production for many years to come.

Since 1924 imports to the United States from France have increased from 232 short tons to 11,163 short tons for 1926. This stimulation will result in considerable additional development of French reserves.

SPAIN

Fluorspar occurs in Spain in a number of places, chief of which are the provinces of Barcelonia, Gerona, Cordoba and Guipuzcoa. Domestic requirements of spar in Spain are between 600 and 700 tons per year.

The Berta mine near Papiol, Barcelona, was opened a number of years ago for lead. Extensive development was accomplished, but the lead was too lean to pay. The vein is known for a length of five kilometers and is from two to three meters in width. The waste dumps here are similar to the English hillocks and contain about 30,000 tons of gravel spar that would be available through milling. The underground reserves amount to not less than 650,000 tons; probably muchmore than that will actually be found ultimately. The lead content of the ore assists materially in lowering production costs. Recently this mine has been reopened and the mining of spar started. Labor is paid 7.50 pesetas ($1.07) per day as wages. A small mill with capacity for 150 tons per eight hours has been installed and on three shift operation could supply about 450 tons per day.

The Province of Guipuzcoa has three known spar deposits, only one of which has operated in recent years. It is known as the San Maximiliano mine. No data is available on which to base an estimate of reserves, though it is reported that sufficient ore is present to continue present operations several years and would indicate fairly large reserves.

ITALY

The most important and largest deposit of fluorspar in Italy is located about 21 miles north of Bolzano. The veins are mined through a series of tunnels and adits and are opened over a length of several thousand feet. The vein material averages approximately 80 percent high grade fluorspar and is about 3 to 6 feet wide.

The ore reserves are estimated to be 200,000 tons proved ore, 250,000 probable ore and 600,000 possible ore, or a total of 1,050,000 tons of fluorspar in that district north of Bolzano.

Production costs are between $2.50 and $5.00 per ton. Freight from Bolzano to Trieste, port of shipment, including haulage from mines to Bolzano, is about $7.50 per ton, making a total cost on board ship of $12.50 per ton. The high grade lump and ground spar are exported to the United States for the most part. Domestic consumption of spar in Italy is small, amounting to approximately 1,500 metric tons per year.

Several other small deposits of spar are reported to exist in Italy, though of little importance as transportation makes cost of production prohibitive.

SOUTH AFRICA

There are several deposits of fluorspar in South Africa of possible commercial importance. The three largest and most important are in the Transvaal in the Zeerust District southeast of Ottoshoop. Data regarding total reserves is limited, but the known ore bodies are not very large and without additional discoveries South Africa will not produce in excess of 25,000 tons. The possibility for additional discoveries, however, is good.

Open pit mining is the method followed in producing the ore. Native labor is employed at very low wages, a few pence a day, and simple hand sorting with some screening to remove fines is the preparation given the shipping product. The spar is low in silica and high in fluorite, making acid grade material for the most part.

Fluorspar is also reported in more or less quantities associated as a gangue with tin ore in the Waterberg tin district. This may be a source of future production of fluorspar, though at present of little importance.

CHINA

Several small deposits of fluorspar are worked in a haphazard way in south Manchuria along the South Manchuria railway. At Shantung fluorspar occurs associated with lead. These deposits are not large as far as is known. Practically no major development has been done, so little is known regarding reserves.

NORWAY

There are two large deposits of fluorspar in Norway, one of which occurs in the County of Telemarken and the other at Kongsberg, in the extreme southeast part of the country.

River transportation to the coast is available to both of these deposits.

At the Tveitstaa deposit located in Telemarken County, Mr. Carl C. Riiber, a Norwegian Government mining engineer, estimates the reserves of proved and probable ore to be in excess of 500,000 tons above the present adit level. The possible ore below this horizon should be equally as much, making a total ore reserve at the deposit of approximately 1,000,000 tons.

Less is known of the Kongsberg deposits, but from all available data the reserves of that and other smaller deposits in the district will equal the Tveitstaa deposit, making a total reserve of fluorspar in Norway something in excess of 2,000,000 tons.

Some activity in the development of these deposits is now being undertaken. Hydro-electric power is available in both districts.

CANADA

There are two districts of some importance in Canada producing fluorspar, given below as follows:

(1) British Columbia - Rock Candy Mine

The deposit of fluorspar here occurs in a fracture zone and vein formation associated with quartz and to a less extent with copper and iron sulphides which are deleterious elements, causing the finished spar to be of inferior grade. Locally some of this spar is used, but freight rates to eastern markets are prohibitive. In the aggregate, there is considerable tonnage of the mineral in the ground, but it is of little commercial importance and marketable reserves are therefore of no importance.

(2) Ontario - Madoc District

This district has produced the greater part of the fluorspar mined in Canada, and is in the central, southeastern part of Ontario. The ore occurs in steeply dipping veins, ranging from a few inches to as much as seventeen feet in width in places. The associated minerals are barite, calcite and celestite, named in the order of their abundance. Barite causes the marketable spar to be of inferior quality. Commercial reserves are not large under present conditions.

AUSTRALIA

Deposits of fluorspar occur in Australia in New South Wales, Queensland and Victoria. The most important and largest of these is at Carboona in the Tumbatumba division of New South Wales which supplies spar to the steel works at New Castle.

The reserves of fluorspar here are potential rather than actual at the present time, as they are for the most part distantly located from cheap transportation either by rail or water. With transportation facilities, the aggregate tonnage would be large.

SWITZERLAND

Fluorspar occurs in Switzerland associated with lead. In the Trappist mine district the vein is about one meter wide. There is considerable tonnage of spar available, but lack of transportation and a close market render the great part of the tonnage of little commercial value.

MEXICO

In Mexico, fluorspar is found in Aguascalientes, Coahuila, Chihuahua, Durango, Guanajuato, Guerrero, Jalisco, Mexico, Puebla, Queretaro, San Luis Potosi, Sonora and Zacatecas, of which the deposits in San Luis Potosi are the only ones of commercial importance presently. The spar from this latter district is shipped to Monterey for use in the manufacture of steel. The tonnage of spar in the aggregate is quite large, but cannot be considered as ore, due to lack of transportation and its remote location.

INDIA

Minor deposits of fluorspar occur in the central provinces of India, but are of no commercial importance under present market conditions, other than that they indicate the possibility that exploration may develop further deposits, larger in size, capable of exploitation.

ARGENTINA

In Cordoba, in Argentina, fluorspar occurs in fissure vein deposits ranging in width from one foot up to several yards in the case of lode formations. The deposits are reported to be large and of good grade spar. The remote location and lack of cheap transportation render them of no commercial importance.

BRAZIL

There are small deposits of fluorspar in the State of Minas Teraes in Brazil. The spar is produced as a by-product from the mining of other ores, but the tonnage is negligible.

BOLIVIA

Fluorspar is found in a number of places in Bolivia, but the deposits are small, transportation facilities are poor and the deposits are therefore of no commercial importance.

GUATEMALA

In Guatemala there are a number of places where fluorspar is found, but due to the remote location of these deposits they are of no commercial importance presently.

CUBA

Small deposits of fluorspar exist in the province of Oriente in Cuba, but are of doubtful commercial importance. The reserves are of little extent.

PERSIA

Occurrences of fluorspar are found in Persia, but are of no commercial importance, due to the small, erratic nature of the deposits.

SUMMARY

The foreign sources will continue to be large producers of fluorspar. Large deposits, low labor costs and favorable mining conditions will make the fluorspar available as fast as is required abroad with a large surplus available for export to the United States.

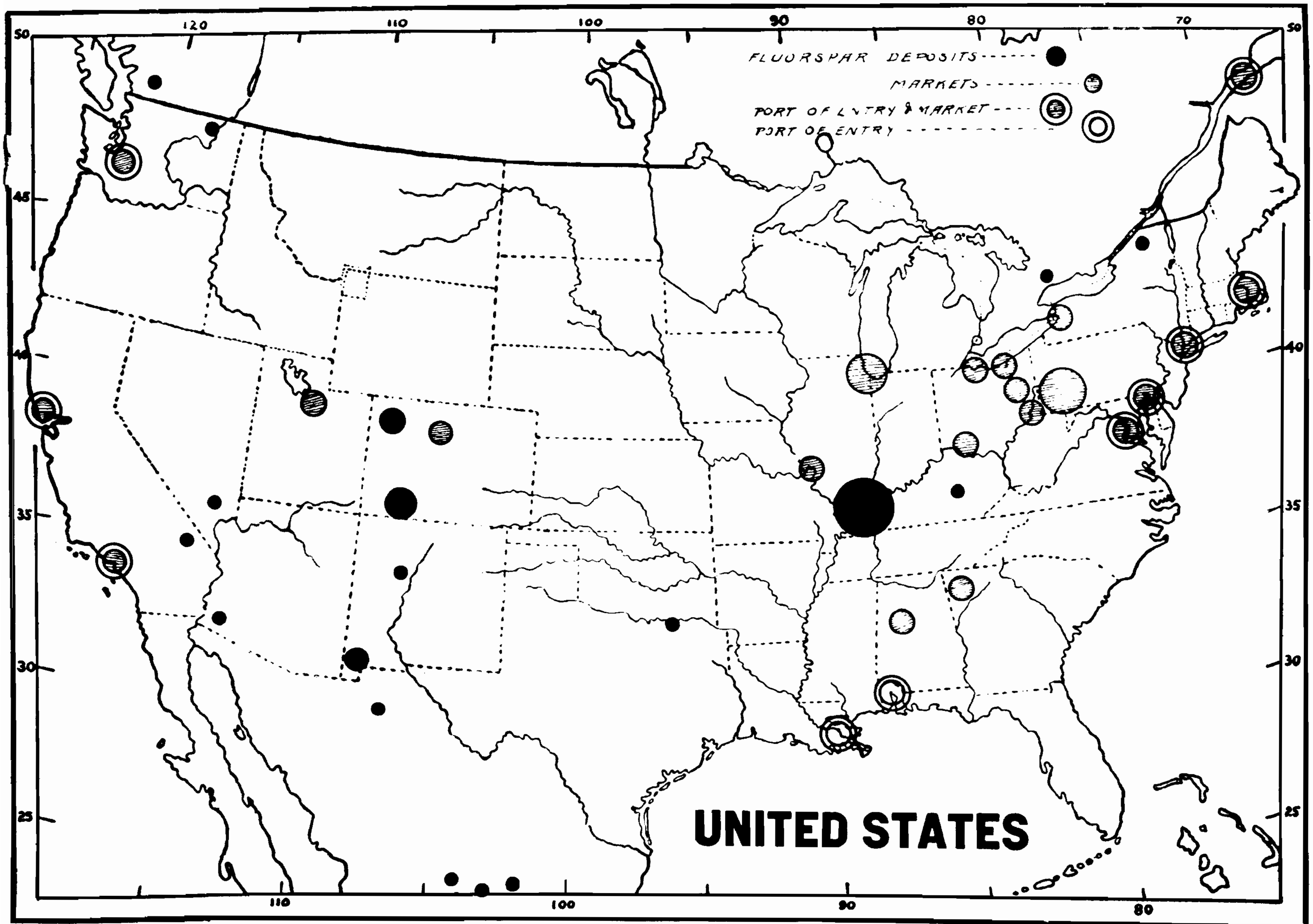
Increased production is to be expected from Italy, Spain, Germany and France, which must for the most part find a market in the United States. Production in other countries, i.e., England, South Africa, etc., will remain about as during 1926.

(B) DOMESTIC RESERVES

Deposits of fluorspar in the United States of known commercial importance are confined to four states; Illinois, Kentucky, Colorado and New Mexico. Of these Illinois and Kentucky supply eighty to eighty-give percent of domestic production.

(1) Illinois-Kentucky Districts

This district lies in the extreme southern part



THE HARTER SCHOOL SUPPLY CO., CLEVELAND, OHIO of Illinois in Hardin and Pope Counties and the western part of Kentucky in Crittenden, Caldwell and Livingston Counties. The Ohio river is the boundry between the two states, dividing the district into two parts.

This district lies on the eastern side of the great mid-continent uplift known as the Ozark Mountains. The surface is rough to semi-mountainous and deeply dissected by stream erosion. Faulting controls the trend of certain of the ridges; in certain limestone areas underground drainage has produced typical "sink holes" topography; but with these modifications, the surface exhibits the orderly topography of mature stream erosion of an elevated tract of flat lying sedimentary rocks.

The rocks are flat lying sedimentary formations, limestone, sandstone and shale, varying in age from late Devonian to late Mississippian. The sedimentary beds are intruded by dikes and sills of dark, basic, igneous rocks to a limited extent.

It has just been said that the sedimentary rocks are flat lying; that as a general statement is true, but locally the beds incline markedly from the horizontal due to faulting and displacement. The remarkable geological feature is an extensive network of faults by which the rocks have been cut up into blocks of varying straight-sided shapes and sizes. These blocks habe been displaced vertically in relation to one another, bringing into juxtaposition at the surface beds of different ages and characters. The vertical displacement of these faults varies up to as much as 1500 feet. Many of them are open fractures, that is, do not contain vein filling. The others are to varying extent vein-filled, the filling being calcite, fluorspar, the sulphide ores of zinc and lead traces of copper-iron sulphide and here and there barite and other minor minerals.

The uplift of the Ozark region began in late Mississippian time. Without reference to the details of this movement it may be considered to have been completed at the close of Pennsylvanian time; this area was then covered by many hundreds of feet of sedimentary rocks that have since been removed by erosion. Before erosion had proceeded far, probably accompanying the uplift, the district was invaded at depth by great masses of molten basic igneous rocks from which relatively small amounts (dikes) reached higher horizons through fissures (faults) in the overlying sedimentary formations and here and there worked horizontally outward from these fissures along the planes of bedding forming sills. Extensive faulting resulted not only from the displacement on a grand scale caused by the intrusion itself, but also (and perhaps mainly) from the contraction of the magma on cooling, permitting irregular settling of the overlying strata. Certain channels in some of the faults served as escape for mineralized solutions from the magma. From these solutions were deposited most of the mineral matter now filling portions of certain of the faults. It is probable that the faulting continued through the period of unrest, lasting from the beginning of the intrusion until congelation of the magma was complete. This was a long time. There were probably long periods of quiescence broken by periods of disturbance during which new faults were formed and new movements along old faults took place. Coincident with these alternating periods of disturbance there were several periods of vein filling. Vein-filled fissures were then reopened and mineral deposition resumed. This may have happened several times in the same fissure. During all of this time erosion of the surface was in progress and it is probable that a considerable portion of the many hundreds of feet of sediments lying above the present surface when the Ozark uplift began were removed before the congelation of the magma was complete and faulting and vein filling had finally subsided.

Types of Deposits. There are three types of deposits, viz: (a) Formed in Fissures, fissure veins, (b) formed by weathering of fissure veins, gravel deposits, (c) formed by replacement of limestone beds, bedded deposits.

Fissure vein deposits are the most important and furnish an increasingly large proportion of the output. Of these the Good Hope-Rosiclare vein in Hardin County, Illinois, has produced perhaps more than one-half of the total output of the district. It extends from a point in the Ohio River about a mile below Rosiclare northward for about three miles where it is terminated by a cross fault. It may extend southward across the river into Kentucky but no trace of it in this direction has been discovered beyond the workings of the Extension Mine on the property of The Franklin Fluorspar Company. This fault has a displacement of only about 200 to 250 feet. It is not, therefore, distinguished either for length or throw but it is by far the most heavily mineralized fissure in the entire district.

The fluorspar in the Good Hope-Rosiclare vein extends in places from wall to wall, in other places it occupies one side of the vein and calcite the other; it occurs also as a central band with calcite on both sides and finally it is often intermixed irregularly with calcite particularly as depth is attained. Galena and sphalerite are found throughout this vein in amounts varying from a mere trace up to several percent of the vein content.

Other mineralized fault fissures are in their general features similar to the Good Hope-Rosiclare vein. They differ of course in trend, dip, throw, degree of mineralization and in color, crystallization and general appearance of the calcite and fluorspar. The other important veins in Illinois are the Blue Diggins and the Daisy, which occur a short distance west of the Good Hope-Rosiclare vein on the properties of The Franklin Fluorspar Company and the Rosiclare Lead and Fluorspar Mining Company and the Empire Vein near

Golconda in Pope County. The most important producing veins in Kentucky are the Tabb, Columbia, and La Rue. There are many others of less importance.

The gravel deposits have been an important source of production, especially in Kentucky. In the future, a much smaller proportion of the production will be afforded by them for the reason that most of them doubtless have been discovered and many have been exhausted. The gravel deposits are indebted for existence to the superior resisting power of fluorspar to the agents of rock weathering. They occur in the residual clay above spar laden fault fissures. The occurrence of gravel spar in clay, however, is not dependable evidence of a mineable fissure vein in the rock under the clay. By deep weathering a very considerable deposit may be concentrated from a very small or a lean deposit in the fissure vein. The quantity of gravel spar in any deposit depends upon the depth of weathering, the size and richness of the fissure vein deposit once existing above the residual clay and the amount of residuum remaining in place above the unweathered rocks. The mining of a gravel deposit is, therefore, an uncertain undertaking. The deposit may be rich or lean, large or small, but little of this information is practically obtainable in advance of actual excavation. The amount of spar recoverable varies from a few wagon loads up to several thousand tons.

The bedded deposits of commercial importance are confined, so far as known, to one locality, Spar Mountain, in Hardin County, Illinois, near the village of Cave in Rock. Spar Mountain is a prominent bluff rising to a height of about 250 feet above the surrounding country. About one-half way up the bluff there is exposed the Rosiclare sandstone-shale formation which is here only a few feet thick. The shale, where present, lies beneath the sandstone. Above and below the Rosiclare formation are limestone beds. The fluorspar deposits are in limestone immediately under the Rosiclare formation; several, including Cave in Rock, Lead-hill, Green and Cleveland, have been mined.

The Cleveland deposit is typical of the group. It is opened by an adit from the face of the hill. Its long dimension is about 700 feet. It has an extreme width of about 200 feet. There are three beds of spar of a combined thickness of ten to twelve feet. The upper bed is a replacement of a pure limestone layer of a maximum thickness of about four feet. Below this is a sandy limestone about two feet thick, only partially replaced. The spar in this bed is too low grade to be in itself mineable. Beneath this bed is another strata of purer limestone which is replaced through a variable thickness not edceeding two feet over the greater part of the mine. The upper bed has the greatest horizontal extension and the highest grade spar, the lowest bed the least horizontal estension. The strata dip toward the long axis of the deposit at a slight angle forming a very flat trough which pitches gently into the fluff. The limbs of this shallow trough do not dip regularly but exhibit ill-defined "flats" and "pitches", the ore being thickest on the flats and thinnest on the pitches. On the edges of the deposit opposite the long axis the contact between the sandstone and the limestone rises rather sharply and coincidentally the fluorspar disappears. In this mine the base of the Rosiclare formation is shale, which varies from an inch or two to four feet in thickness. There are some open cavities lined with crystals mainly of calcite and fluorspar, with some galena, sphalerite and barite. The barite shows a marked preference for the outer edges of the deposit. The Cleveland and other deposits of the same type are thickest in the center, the type shape being that of a very flat inverted cone. The apex of the cone in the Cleveland Mine is on a distinct fracture.

The foregoing briefly pictures the nature, character and extent of the fluorspar ore deposits in the Illinois-Kenticky district. For the sake of brevity the long detailed computation tabulation of the deposits has been eliminated and the following table has been inserted showing in condensed, classified form the estimated ore reserves of the district in terms of finished product.

Proved Ore is classified as ore in place which has been partially or wholly developed on one or more levels.

Probable Ore is a reasonable extension of ore developed by one level only.

Possible Ore is that which may conservatively be expected in territory unexplored except for diamond drilling or shallow surface work.

(A) ILLINOIS

Name of Vein	Proved Ore		Probable Ore		Possible Ore		Total	
Rosiclare	200,370	Tons	329,000	Tons	545,000	Tons	1,074,370	Tons
Daisy	40,790	"	31,100	"	125,000	"	196,890	"
Blue Diggings	12,400	"	30,600	"	150,000	"	193,000	"
Empire	1,500	"	5,000	"	25,000	"	31,500	"
Bedded Deposits) Cave-in-Rock)	13,300	"	32,700	"	150,000	"	196,000	"
Hamp, Stewart, Douglas, Indiana, Griffith, Lee, Martin, Stone, Scott, etc.	9,000	"	26,000	"	145,000	"	180,000	"
Total Illinois	277,360	"	454,400	"	1,140,000	"	1,871,760	"

(B) KENTUCKY

Tabb	79,000	"	101,000	"	810,000	"	990,000	"
Columbia	45,800	"	50,000	"	200,000	"	295,800	"
La Rue	5,000	"	6,000	"	50,000	"	61,000	"
Hearne	12,000	"	15,000	"	100,000	"	127,000	"
Pope	5,000	"	6,000	"	75,000	"	86,000	"
Marion	6,000	"	7,000	"	25,000	"	38,000	"
Holly & Weller	7,000	"	9,000	"	50,000	"	66,000	"
Bonanza	5,000	"	7,000	"	60,000	"	72,000	"
Crider	1,000	"	3,000	"	15,000	"	19,000	"
Eaton	500	"	1,000	"	15,000	"	16,500	"
Klondyke	10,000	"	20,000	"	100,000	"	130,000	"
Miscel	7,000	"	25,000	"	150,000	"	182,000	"
TOTAL	183,300	"	250,000	"	1,650,000	"	2,083,300	"
Total Illinois-Kentucky	460,660	"	704,400	"	2,790,000	"	3,955,060	"

The above estimates are conservatively based both on the conditions now existing and on the history of production from the various veins in the district over a period of more than fifteen years. The figures given for possible ore are ultra conservative. Other estimates made by reputable engineers, familiar with conditions, place the tonnage in this classification several times higher. However, realizing that ore as defined earlier in this paper must be mined at a value comparable with that received on the present market, it has seemed better to underestimate rather than over estimate the total ore reserves, if there is to be any error. It is understood that any increase in the price obtained for spar, over that obtained on the present market, will result in making available large tonnages of lower grade crude ore now unprofitable, which would increase the total estimated reserves indicated above.

(2) COLORADO.

There are several fluorspar deposits in Colorado though with exception of two, one near Wagon Wheel Gap and the other at North Gate, they are of little importance due to remote location and the inferior grade of the crude ore. Reserves are difficult to compute due to lack of development. A brief description of the principal properties follow:

(a) Wagon Wheel Gap.

The vein outcrop maybe traced about 2,500 feet along a steep hillside east of Goose Creek. The walls of the vein are chiefly Andesite with rhyolite and quartz latite in lesser quantities.

The vein is of the fissure type, very irregular in width ranging from a maximum of 25 feet to a minimum of a few inches but averages about six to eight feet. The vein filling consists of fluorspar, barite, fragments of country rock and gangue in varying proportions. The character of the gangue causes the silica content of the finished spar to be high.

(b) North Gate.

This deposit extends about a mile along the side of a long, low hill which rises four to five hundred feet above the valley floor at the railroad where the elevation is about 8,000 feet. The hill in which the deposit occurs is principally coarse grained pink granite intruded by numerous dikes. The shear zone or vein between these granite walls varies greatly in width and the ore body or vein filling is an interlaced network of lenses of spar, wall rock, gangue and dike material. The walls are poorly defined due to the shear zone in which the ore body occurs.

(c) Other deposits are known in the Jamestown District in Boulder County and have been developed to some slight extent by the Emmet, Argo, Alice and Warren Mines.

ORE RESERVES

The fluorspar ore reserves of Colorado are estimated as follows, in terms of finished spar:-

Proved Ore	25,000	Tons
Probable "	40,000	"
Possible "	60,000	"
Total "	125,000	"

(3) NEW MEXICO

A number of small fluorspar deposits are known in New Mexico, located in Dona Anna, Sierra, Grant, Luna and Bernalillo Counties. Some development on a small scale has been done but nothing of major importance has resulted. The quality of the spar is poor due to a high silica content universially true of all the deposits and this together with the isolated location and small extent of the ore bodies results in high production costs. It is entirely possible that future discoveries and better transportation facilities may change the aspect of things but presently little future production may be expected from New Mexico. The principal deposits are in Dona Anna County.

The fluorspar reserves of New Mexico are estimated in terms of finished product as follows:

Proved Ore	10,000	Tons
Probable "	30,000	"
Possible "	40,000	"
Total "	80,000	"

(4) OTHER STATES

Arizona, Utah, California, Washington, Nevada, New Hampshire and Texas have small deposits of fluorspar but due to various conditions, i. e., quality of ore, isolated location, lack of transportation, small ore bodies, etc., they are of little consequence as far as the tonnage of ore in place is concerned. Any change in this situation is not immenent but is a possibility for the distant future and at that time Nevada, for instance may, with transportation, develope considerable fluorspar reserves. At the present time the total reserves of these states including proved, probable and possible ore does not exceed 80,000, most of which is classed as possible, rather than proved or probable.

SUMMARY

The reserves of fluorspar in the United States are ample to take care of its total consumption for more than twenty-five years, probably much lower; or at the present rate of Domestic production, approximately forty years would be required to exhaust them. This, speaking of the industry as a whole is true, but should be modified with respect to Acid Lump requirements of the future which are liable to increase rather than decrease. In that event the United States would have to look to foreign sources for additional acid grade material. All the other grades are available now at practically any production rate desired and will be in the future if, and only if development is kept abreast of mining operations as it should be to have adequate ore available for extraction.

VI. CONCLUSIONS AND RECOMMENDATIONS

The foregoing study shows that (1) there is ample reserve of fluorspar in the United States to take care of its requirements for many years, (2) if developed and scheduled on a production rate equal to at least seventy-five percent of the annual domestic requirements, (3) which will permit a sufficient increase in production rate in time of war to take care of increased wartime requirements.

It is therefore recommended that:

FIRST Tariff on fluorspar, excepting only Acid Grade material be increased by 50 percent which will amount to $2.50 per short ton, which will:

(a) Curtail importation of foreign spar somewhat.

(b) Allow domestic spar to penetrate east of Pittsburgh into markets now enjoyed by imported spar. To do that,no increase in price on domestic spar would result, but benefit would be had in greater volume.

(c) Schedule domestic operations at annual production closer to peak wartime demand, safe guarding the United States in time of military stress.

(d) Lower domestic production cost, as result of larger volume, relieving burden on domestic producer now felt.

SECOND Encourage, through various Governmental agencies, and by research, better understanding of efficient concentration of fluorspar crude ore to obtain better recovery of the higher grade products, i.e., Acid and No. 1 grades.

The first of these recommendations of the utmost importance, if the United States is to continue to remain independent of foreign fluorspar in the future.

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